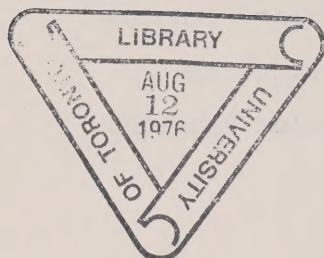# Transmission-technical

Submission to the
Royal Commission on
Electric Power Planning
with respect to the
Public Information Hearings

TRANSMISSION - TECHNICAL

Submission of

ONTARIO HYDRO

to the

Royal Commission

On Electric Power Planning

with respect to the

Public Information Hearings

March, 1976

3	<u>TRANSMISSION</u>	Lines, Stations and Environmental Assessment

<u>VOLUME 1</u>

3.1   <u>TRANSMISSION LINES</u>

3.2   <u>TRANSFORMER AND SWITCHING STATIONS</u>

<u>VOLUME 2</u>

3.3   <u>TRANSMISSION LINES AND STATIONS ENVIRONMENTAL ASSESSMENT</u>

TABLE OF CONTENTS

(i)

(ii)

52
53
54
55

Line
Number

11
12
13
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ac	alternating current
acsr	aluminum conductor steel reinforced
BIL	Basic Impulse Insulation level
CSA	Canadian Standards Association
CVT	Capacitive Voltage Transformer
DACS	Data Acquisition and Computing System
dB	decibel
dc	direct current
DESN	Dual Element Spot Network
EHV	Extra High Voltage
HPOF	High Pressure Oil Filled (Pipe Type)
HVDC	High Voltage Direct Current
Hz	Hertz
IEEE	Institute of Electrical and Electronic Engineers
kcmil	1,000 circular mils
kHz	kilohertz
kV	kilovolts
lb/ft^2	pounds per square feet
LPOF	Low Pressure Oil Filled
MHz	Megahertz
mph	miles per hour
MVA	Megavolt Amperes
MVAR	Megavolt Amperes Reactive
MW	Megawatts
PLC	Power Line Carrier
psi	pounds per square inch
psig	pounds per square inch gauge
PT	Potential Transformer
R/W	Right of Way
SF6	Sulphur Hexafluoride
UHV	Ultra High Voltage
ULTC	Under Load Tapchanger
VAR	Volt Ampere Reactive

3 TRANSMISSION: Lines, Stations and Environmental
          Assessment

3.1 Transmission Lines

3.1.1 Introduction

3.1.1.1 Functions and Purpose

A delivery system is required to transport
electricity from generating stations where it is
produced to the points of end use.

Generally, individual customers are connected by
sub-transmission lines, i.e. lines at voltages below
50,000 volts (50 kV), to area supply stations.
These stations are supplied by transmission lines
(nominally at 115 kV, 230 kV and 500 kV) which have
adequate capacity to supply several such stations.
Some large industrial customers are supplied
directly from the 115 kV or 230 kV lines. The
higher voltage lines in turn are connected to
terminal stations and interconnected with one
another and with the generating stations by
additional high voltage lines.

This network of transmission lines forms the
provincial grid and permits a load area to be
supplied from a number of generating stations.

Transmission lines are divided for planning and
operating convenience into two main categories:

(a) Bulk power transmission lines –
  These are the main lines delivering power from
  generating stations to receiving terminal
  stations. On the existing Ontario Hydro system
  some of these lines operate at 500 kV, most
  operate at 230 kV, and a few operate at 115 kV.
  Almost all these lines are overhead.

(b) Area supply lines –
  These lines take power from the bulk power
  transmission system at the receiving terminal
  stations and transmit it to area-supply
  transformer stations. The usual voltage levels
  are 230 kV or 115 kV. These lines are mainly

overhead but are often put underground in urban areas.

The number of miles of line in operation in the system at the end of 1975 were as follows:

Line Voltage	Circuit Miles	Tower Line Miles*
500 kV	645	645
345 kV	3	3
230 kV	7571	5346
115 kV	6769	5199

* Steel tower and wood pole

3.1.1.2   Status of EHV

Up to 1950, electric power demands were satisfied over broad areas of the world by high voltage transmission lines operating at voltages of 230 kV, 138 kV or lower. Growth in the early 1950's made these voltages uneconomic to satisfy future needs and EHV lines operating at 345 kV and 380 kV were constructed in Europe, the United States and Canada. Experience with these early EHV lines brought to light new problems in lightning performance, insulation contamination and radio noise resulting from corona on conductor and conductor hardware.

In the late 1950's, it became clear that there was a need developing for a transmission system with a higher power transfer capability including the ability to transfer large blocks of power over long distances. The development of the generating potential of the Moose River watershed was particularly important in this regard. Lines in the range 345 kV to 765 kV, known as extra-high voltage (EHV) appeared to be the most likely solution. Accordingly, Ontario Hydro undertook EHV technology research at the Coldwater test site, at the laboratories of its Research Division and in collaboration with manufacturers. The broad scope of these investigations included insulation studies, corona on bundle conductors, contamination problems, electrostatic and electromagnetic effects, conductor vibration, hardware design, construction handling of bundle conductors and live-line maintenance.

Some of the significant developments, which have
resulted from Ontario Hydro's EHV research program
have been in such areas as:
-    corona-free suspension assemblies (eliminating
     the need for expensive corona rings)
-    corona loss research (resulting in the
     development of a more accurate corona loss
     formula)
-    the use of guyed structures at 500 kV
-    the determination of allowable voltage stresses
     in bundle conductors (which more closely
     defined the requirements for acceptable
     conductor surface roughness)
-    the development of a spacer-damper (which
     combined the functions of two separate pieces
     of hardware)
-    the development of techniques for bare-hand
     maintenance

In this same period, research on 500 kV transmission
was carried out by a number of U.S.A. and Canadian
utilities. Ontario Hydro adopted advanced concepts
arising out of the work of others, particularly the
data on full-scale switching surge strengths of
insulators and air gaps, new lightning performance
and shielding criteria and construction techniques
such as tension stringing.

Ontario Hydro was the first utility to design and
construct a line for 500 kV operation although
initially it operated at 230 kV. The first
transmission lines operating at 500 kV and higher in
North America were placed in service in the mid-
1960's, including Hydro Quebec's 365 miles of 735 kV
line, which at that time was the highest operating
voltage in the world. By 1973, there were over
11,000 circuit miles of lines in service at voltages
of 500 kV and higher in North America.

3.1.1.3   Status of UHV

It is generally believed that a voltage level above
765 kV, likely in the 1000 to 1500 kV range, will be
required on a number of systems in the world in the
next ten to twenty years. This higher voltage level
is known as ultra high voltage (UHV).

Ontario Hydro is keeping abreast of UHV developments
but considers it unlikely that an ultra high voltage
line will be required in Ontario before 1995.

While there are no commercial installations of power
facilities at the UHV level, there are a number of
test installations throughout the world. Hydro
Quebec's Institute of Research (IREQ) has carried
out a test program to investigate the performance
and determine desirable design parameters for 1200
kV lines.

Project UHV is an American high voltage transmission
research program sponsored by the Electrical
Research Council and funded by the Edison Electric
Institute and Bonneville Power Administration. This
work is being carried out by staff of the General
Electric Company in the United States. Project UHV
was initiated in the late 60's to provide technical
data which would permit utilities to consider the
installation of UHV facilities. Voltage levels up
to 1500 kV have been studied.

In the early 1970's, the American Electric Power
Company (AEP) and ASEA, a large Swedish
manufacturer, in association with the Ohio Brass
Company initiated a ten year research project on
UHV. The objective of the program is to obtain
fundamental knowledge essential to the development
of major equipment and the design of systems, lines
and stations in the approximate range of 1000 kV to
1500 kV. Research has also been carried out in
Great Britain, France, Italy and the Soviet Union.

Much of the work that has been carried out has been
directed towards the following areas of transmission
line design:

-       establishing limits for audible and radio noise.

-       establishing limits for electrostatic induction
        effects.

-       determining a suitable insulation
        design.

-       investigating techniques for live line
        maintenance.

3.1-4

Based on the work carried out to date, it is
believed that it will be possible to design
economical and environmentally acceptable UHV
transmission systems.

Related Material

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January - March 1959, vol. 11, No. 1

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2. The Coldwater Project by J.G. Cassan, pp 3.

3. Instrumentation & related problems at the
   Coldwater Project by J.M. Vanderleck, pp 10.

4. Radio-interference problems at EHV by D.E.
   Jones and J.R. Leslie, pp 18.

5. Voltage - gradient calculations for bundled-
   conductor lines by J. Reichman, pp 23.

6. The corona-loss problem by O. Nigol, pp 28.

7. The insulator-loss problem by A. Elek and O.
   Nigol, pp 36.

8. The problem of EHV line insulation by A. Elek,
   pp 40.

9. The Station insulation problem by H. Linck, pp
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10. The switching-surge problem by W. Watson, pp
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January - March 1961, vol. 13, No. 1

11. The Ontario Hydro Coldwater Project:
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12. Radio interference studies at the Coldwater
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14. Instrumentation for power-loss and
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October – December 1961, vol. 13, No. 4

16. Model study of tower proximity effects on
     conductor gradients by O. Nigol, pp 14.

First Quarter 1962, vol. 14, No. 1

17. Electrostatic ;induction under 230- and 460 kV
     transmission lines by A. Elek, pp 10.

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18. Corona tests on hardware for EHV transmission
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     by A.T. Edwards and J.M. Boyd, pp 1.
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       No.   Research Division Reports

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               transmission methods.

21. 57-467   Corona limit voltages for single
               circuit EHV lines using two conductor
               bundles.

22. 58-1   Corona limit voltages for double
               circuit EHV lines using two conductor
               bundles.

23. E58-22   Proposed 500 kv test line.

3.1-7

1 2 3	55. 61-300 Corona tests on EHV suspension hardware.
4 5 6 7	56. 61-302 Estimates of corona energy losses for the Neelon Jct. - Essa T.S. 460/500 kv transmission line.
8 9 10	57. 61-303 RI tests on station bus at Coldwater, Progress Report No. 3.
11 12 13	58. 61-320 Electrostatic induction between a cable/car and an adjacent EHV line.
14 15 16	59. 61-338 Model study of tower proximity effect.
17 18 19	60. 61-340 Development of corona-free compression joint for EHV line.
20 21 22	61. 61-346 Grounding of towers on the Pinard-Hanmer 460 kv transmission line.
23 24 25	62. 61-359 Corona test on spacer-damper assemblies for EHV lines.

Line numbers 1-55 run down the left margin.

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55. 61-300   Corona tests on EHV suspension hardware.

56. 61-302   Estimates of corona energy losses for the Neelon Jct. - Essa T.S. 460/500 kv transmission line.

57. 61-303   RI tests on station bus at Coldwater, Progress Report No. 3.

58. 61-320   Electrostatic induction between a cable/car and an adjacent EHV line.

59. 61-338   Model study of tower proximity effect.

60. 61-340   Development of corona-free compression joint for EHV line.

61. 61-346   Grounding of towers on the Pinard-Hanmer 460 kv transmission line.

62. 61-359   Corona test on spacer-damper assemblies for EHV lines.

63. 61-360   Control samples for smoothing surfaces of compression sleeves and damaged conductors in EHV line construction.

64. 61-389   Corona tests on station bus at Coldwater, Progress Report No. 4.

65. 62-87   Evaluation of standard insulators for EHV lines.

66. 62-128   VHF interference from EHV stations - Preliminary survey.

67. 62-158   Fault current capability of overhead ground cables.

68. 62-161   Corona tests on EHV suspension hardware.

69. 62-287   RI generation and propagation studies at Coldwater.

70. 62-340 Radio noise and corona tests on
            station bus at Coldwater.

71. E63-84 Breakdown voltage on long air gaps
            and insulator strings.

72. 63-103 Radio noise recording on short & long
            lines. (Results of 3 year period,
            Coldwater 500 kv test line & on a 230
            kv line).

73. 63-105 Grounding of towers on the Hanmer −
            Kleinburg 460 kv transmission line.

74. 63-352 Corona tests on spacer−damper
            assemblies for Hanmer−Kleinburg 500
            kv line.

75. 63-391 Electrostatic induction near EHV
            transmission lines as related to the
            hazards of handling gasoline.

76. 64-23   Basic corona studies.

77. 64-136 Radio noise generation studies at
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78. 64-153 Feasibility study at Coldwater on EHV
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80. 60-95   Radio interference studies for EHV
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Line Number			
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3			Ontario Hydro Coldwater Project by
4			J.M. Vanderleck.
5			
6	84.	61-1019	Safe clearances & protection against
7			shock during live line work by A.
8			Elek & J.W. Simpson.
9			
10	85.	62-115	Probability method for determining
11			insulation of EHV lines by W.H.
12			McCreary & G.R. Tebo.
13			
14	86.	62-1405	Method of evaluating corona noise
15			generation from measurements on short
16			test lines by M.C. Perz.
17			
18	87.	63-1022	Analysis of radio noise from high
19			voltage lines, Part I. Meter response
20			to corona pulses, by O. Nigol.
21			
22	88.	63-1023	Analysis of radio noise from high
23			voltage lines, Part II. Propagation
24			theory by O. Nigol.
25	89.	63-1024	A summary of radio interference
26			studies applied to EHV lines by J.
27			Reichman & J.R. Leslie.
28			
29	90.	CP63-	On the design of bundle conductor
30		1075	spacers by A.T. Edwards & J.M.
31			Boyd.
32			
33	91.	61-226	The Flashover Strength of Extra High
34			Voltage Line and Station Insulation.
35			- A.F. Rohlfs, H.E. Fiegel, J.G.
36			Anderson.
37			
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39			Affects Live Insulation.
40			
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42			Flashover Characteristics of EHV Line
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95. 64-135   Full Scale Surge Testing of VEPCO
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CIGRE Papers

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100. 1962-411 Live line maintenance by T.J.
               Burgess.

101. 1962-413 Ontario Hydro's EHV system, selection
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               arrangement by H.P. Smith, N.J.
               McMurtrie & J.G. Cassan.

N.R.C. of Canada

102. ERC-275   Corona and radio influence voltage
               tests on extra high voltage line
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     1959   Commission of Ontario by G.J. Seaby.

103. ERC-311   Corona and radio influence voltage
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     January   hardware for the Hydro-Electric Power
     1961   Commission of Ontario by G.J. Seaby.

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104. May 28,   Ontario Hydro's 500 kv transmission
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     Winters, IEEE 70TP641 - PWR.

107. Transmission in the UHV Range - J.S. Forrest,
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     McAllister, CEA, October 26, 1971.

3.1.2   VOLTAGES

3.1.2.1   Capabilities

A 500 kV circuit can carry from 4 to 7 times the
amount of power that can be carried on a 230 kV
circuit. The actual ratio depends on transmission
distance and the limits on current carrying capacity
of transmission and station facilities associated
with the two voltage levels.

Circuit capabilities of various voltage levels based
on Reference 1 are shown in Table 3.1.2-1.

TABLE 3.1.2-1

Voltage Level (kV)	Typical Circuit Capability 100 Mile Length (MW)
115	70
230	280
345	800
500	1920
765	4500

During emergencies, larger amounts of power may be
carried over short line lengths. At 500 kV for
example, for lines less than about 50 miles long,
present designs have an emergency capability of
about 3700 MW. This emergency capability decreases
as line length increases.

A comparison of the line cost and the right of way
width requirement for one 2-circuit 500 kV line
compared to four and to seven 2-circuit 230 kV lines
is shown below:

TABLE 3.1.2-2

Number of lines	Per Mile Cost *	R/W Width (ft)
one 2-cct 500 kV	$ 600,000	250
four 2-cct 230 kV	1,200,000	530
seven 2-cct 230 kV	2,100,000	950

* Per Mile Costs do not include property, legal

3.1-14

1   survey, bush clearing or site restoration costs.
2
3   References
4
5   (1) Transmission Line Reference Book 345 kV and
6   Above - Electric Power Research Institute
7   (Book)
8
9 **3.1.3**   OVERHEAD CONSTRUCTION
10
11 **3.1.3.1**   Tower Types
12
13   Typical 230 kV, 500 kV and 765 kV towers are shown
14   in the diagrams of Figure 3.1.3-1.
15
16   Skywires, located at the top of the towers are
17   installed for lightning protection and to carry
18   fault currents.
19
20   The 230 kV structure, Diagram 1, is a 2-circuit
21   configuration, one circuit consisting of three
22   separate phases on each side of the vertical shaft.
23   Each phase consists of one 1.6 inch diameter, 1843
24   kcmil, aluminum conductor steel reinforced (acsr
25   conductor) per phase. The 500 kV, two-circuit
26   conductor, Diagram 3, is similar in general
27   configuration to the 230 kV conductor each phase
28   consists of 4, 0.95 inch diameter, 585 kcmil, acsr
29   conductors forming a 20 inch square. The one-
30   circuit 500 kV structure Diagrams 2 and 5, show the
31   configurations commonly used. The rigid structure,
32   Diagram 2, is referred to as delta and the guyed
33   structure, Diagram 5, is referred to as horizontal.
34   The one-circuit, 765 kV structure, Diagram 6, is the
35   tower used by Hydro Quebec and is shown to
36   illustrate the relative size.
37
38   (a) Pole vs Rigid Lattice Structures
39
40   Diagrams of pole structures are shown in Figure
41   3.1.3-2. Some people have expressed a
42   preference for pole type structures. Table
43   3.1.3-1 shows the difference in weight and cost
44   of pole and lattice structures. The pole
45   structures are considerably heavier and
46   costlier compared to lattice structures.
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51   3.1-15
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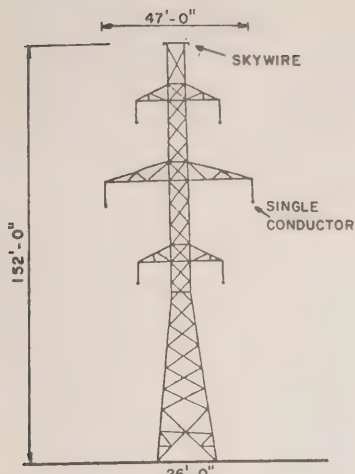
47'-0"
SKYWIRE
SINGLE CONDUCTOR
152'-0"
26'-0"
230kV 2-CCT
$ 300,000 / MILE
DIAGRAM 1
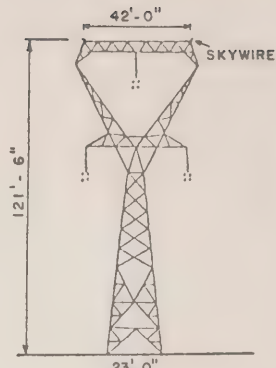
42'-0"
SKYWIRE
121'-6"
23'-0"
500kV 1-CCT
$ 280,000 / MILE
DIAGRAM 2
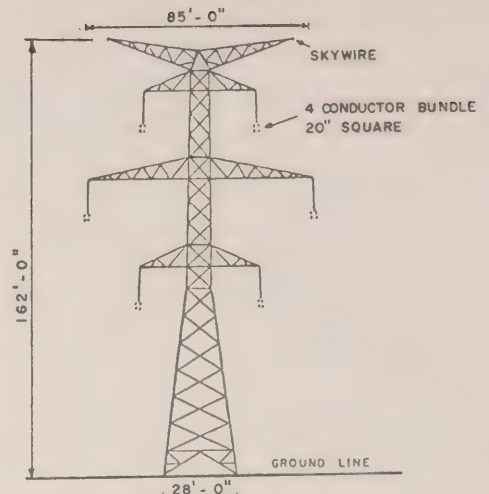
85'-0"
SKYWIRE
4 CONDUCTOR BUNDLE 20" SQUARE
162'-0"
GROUND LINE
28'-0"
500kV 2-CCT
$ 600,000 / MILE
DIAGRAM 3
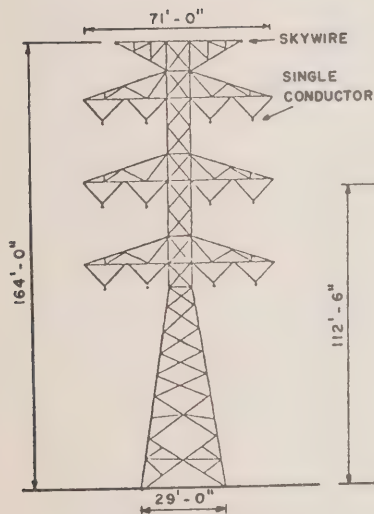
71'-0"
SKYWIRE
SINGLE CONDUCTOR
164'-0"
29'-0"
230kV 4-CCT
$ 630,000/ MILE
DIAGRAM 4
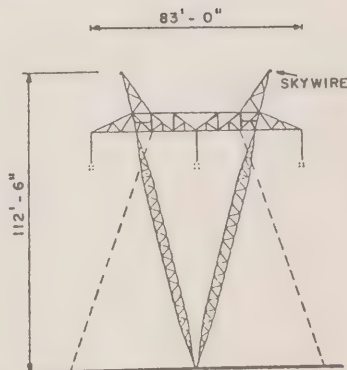
83'-0"
SKYWIRE
112'-6"
500kV 1-CCT
$ 248,000 / MILE
DIAGRAM 5
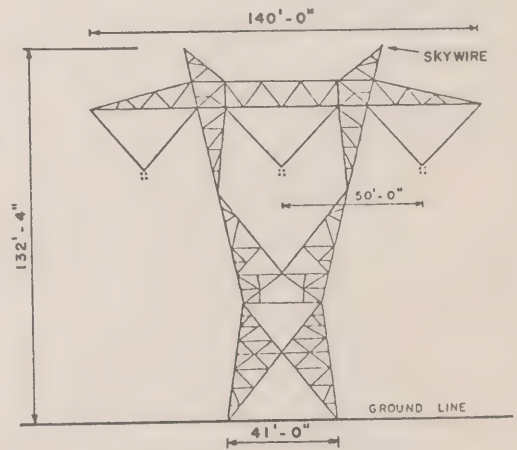
140'-0"
SKYWIRE
50'-0"
132'-4"
GROUND LINE
41'-0"
765kV 1-CCT
$ 660,000/MILE
DIAGRAM 6

PER MILE FIGURES DO NOT INCLUDE PROPERTY, LEGAL SURVEY, BUSH CLEARING OR SITE RESTORATION COSTS, AND ARE IN 1976 DOLLARS BASED ON USE OF 58 SUSPENSION, 4 LIGHT ANGLE, 1 MEDIUM ANGLE AND 3 HEAVY ANGLE TOWERS FOR A 10-MILE SECTION.

TYPICAL TRANSMISSION SUSPENSION TOWERS

THE HEIGHTS AND GROUND LINE DIMENSIONS ARE
MINIMA FOR THE TOWER TYPES SHOWN

FIGURE 3.1.3-1

80'-0"

31'-6"

165'-0"

132'-0"

4'-3"

5'-0"

GROUND LINE
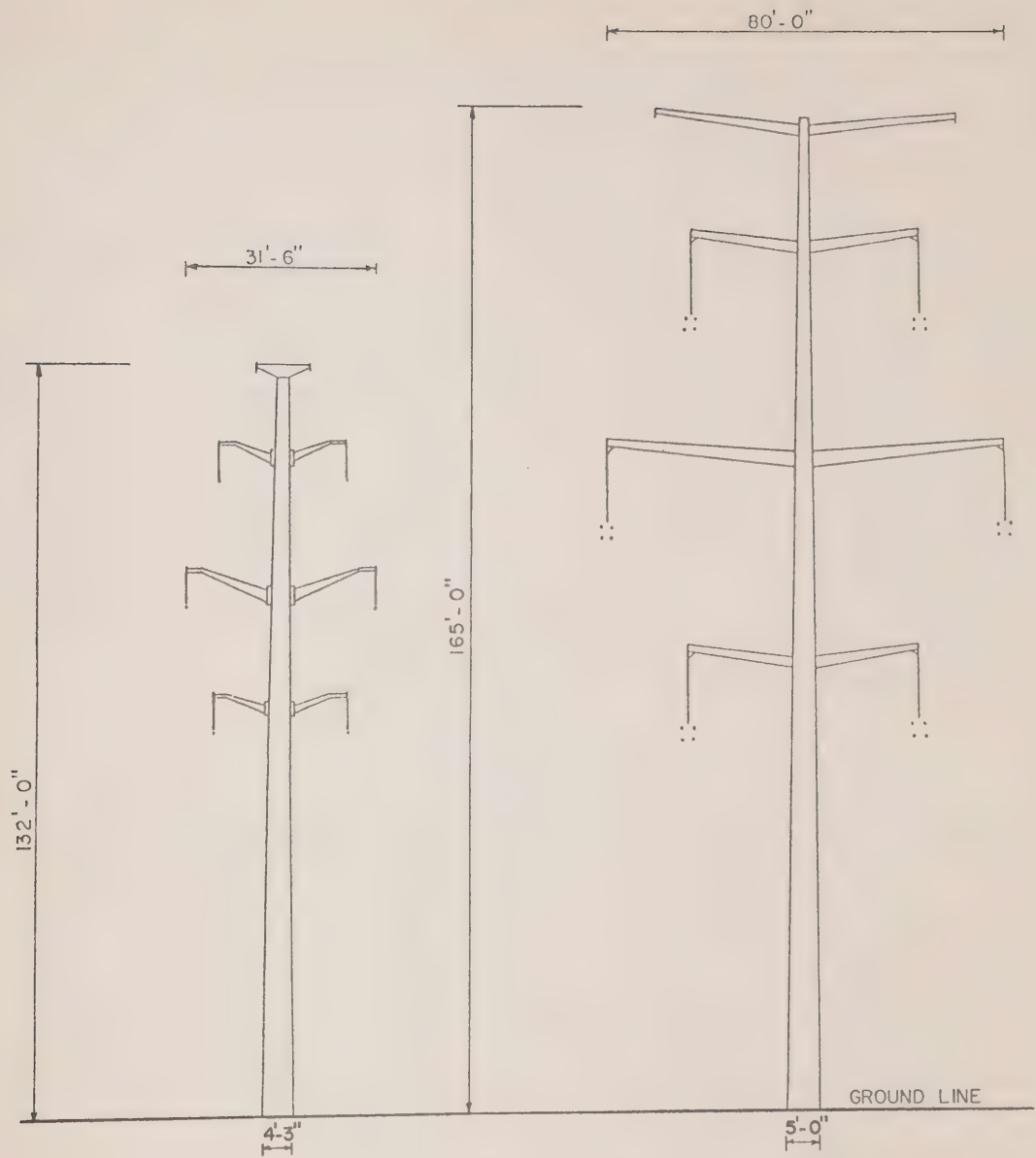
230kV 2-CCT
SUSPENSION (straight line) POLE STRUCTURE

$360,000/MILE

500kV 2-CCT
SUSPENSION (straight line) POLE STRUCTURE

$1,000,000/MILE

FIGURE 3.1.3-2

TABLE 3.1.3-1

Weights and Installed Cost Comparison
Lattice vs Pole Structures

230 kV, 2-cct

Lattice Structures			Pole Structures		
Structure Type	Weight Structure Only (#)	Structure Installed Cost ($)	Structure Type	Weight Structure (Only #)	Structure Installed Cost ($)
Suspension(S)	17,300	25,000	S	41,850	50,400
Light Angle(L)	22,300	32,000	L	47,000	57,700
Medium Angle(M)	45,000	63,000	M	80,750	108,000
Heavy Angle(H)	58,000	90,000	H	148,000	194,000
Cost per Mile = $300,000			Cost per Mile = $493,000		

500 kV, 2-cct

Lattice Structures			Pole Structures		
Suspension(S)	40,400	55,000	S	98,000	120,000
Light Angle(L)	52,800	73,000	L	137,000	158,000
Medium Angle(M)	108,700	189,000	M	226,000	285,000
Heavy Angle(H)	152,000	250,000	H	230,000	339,000
Cost per Mile = $600,000			Cost per Mile = $1,000,000		

Structure costs are representative of total installed
cost of structure with foundation, but do not include
conductor and stringing costs. The basis for per mile
costs are described in (b).

(b)   Effect of Line Angles

Only suspension (or straight line) towers are
shown in Figure 3.1.3-1. In a transmission
line, turns in the direction of the line (i.e.
deflection angles) are taken by angle towers as
illustrated in Figure 3.1.3-3. The per mile
costs, in 1975 dollars, shown in Figure 3.1.3-1
and Table 3.1.3-1 are based on a 10-mile
section in which there are 58 suspension
towers, 4 light angle towers, 1 medium angle
tower and 3 heavy angle (or anchor) towers.
This is representative of the average usage in
Southern Ontario. In Northern Ontario, the
spans could be longer and the relative number
of angle structures less. Table 3.1.3-1 shows
the higher cost of angle and dead-end
structures compared to suspension structures.
From a purely standpoint, therefore, turns in
the line should be kept as few as possible.
The angle and dead-end structures are more
massive and, therefore, have a greater visual
impact than the suspension structures.

3.1.3.2   Foundations

Figure 3.1.3-4 shows the more commonly used
foundations. The augered or cast-in-place footing
has a wide application in Southern Ontario. Augered
footings can not be used in rocky soils or soils
that are too weak to hold their shape until the
concrete is poured.

The grillage type footing is made up of steel
sections usually rolled angles, channels and beams.
Grillages are generally used for the lower range of
footing loads and in some instances where augering
equipment cannot be taken in to the site.

The pad and pier type footing is made up of steel
reinforced concrete formed to shape. Pad and pier
footings are suitable for heavy loads where augered
depths would be impractical or where soil must be
supported while concrete is being poured.

SUSPENSION
ATTACHMENT

SUSPENSION (V1S)
LIGHT ANGLE (V1L)

DEAD - END
ATTACHMENT

MEDIUM ANGLE OR SEMI - ANCHOR (V1M)
HEAVY ANGLE AND ANCHOR (V1H)

COST OF DEADENDING = $16,000 MORE
PER TOWER THAN SUSPENSION ATTACHMENT

V1S

V1L
0° - 6°

V1M
6° - 30°

V1H
30° - 60°

V1S

V1H

STATION

SHOWING HOW LINE ANGLES ARE MADE

FIGURE 3.1.3 - 3

GROUND LINE

REINFORCING
STEEL CAGE

POURED
IN PLACE
CONCRETE

10' - 40'

2 1/2' - 7'

OPTIONAL

6' - 14'

AUGERED TYPE

STEEL ANGLE
FOOTING STUB

8' - 12'

ROLLED CHANNEL
SECTIONS

STEEL
BEAMS

GRILLAGE TYPE
6'- 9' SQUARE

GROUND LINE

FORMED
CONCRETE

REINFORCING
STEEL

12' - 20'

2'- 4'

12' - 35'

PAD AND PIER TYPE

FOUNDATION TYPES

FIGURE 3.1.3- 4

3.1.3.3   Line Mechanical Loadings

The components of a transmission line, the structures, foundations, conductor, insulators and hardware, must be capable of sustaining the mechanical loading designed into the line as well as the loading imposed as a result of weather conditions of temperature, wind and icing. The severity of the weather conditions for which a given line is designed depends on the area of the province and the system security requirements for the line. The mechanical loadings for tower design are shown in Table 3.1.3-2.

(a)   Loading Areas

The Canadian Electrical Code (C.S.A. Standard C22.3 No. 1) divides much of the province into two loading areas which indicate heavy and medium ice and wind loading conditions (see Figure 3.1.3-5). The most northern part of the province is unclassified, because of the lack of sufficient weather statistics.

Loadings for tower design are based on accumulated experience as well as the available weather reports. However, to serve as a check on the actual values used for wind velocity and ice formation in areas where weather conditions have been severe, a study was contracted out to a consulting firm with expertise in meteorology (1). This study confirmed the adequacy of the design loading. For the more northern parts of the province, where data is scarce, a study is underway to provide a firmer base upon which to calculate design loadings.

Ontario Hydro defines various security classifications for transmission lines depending on a line's ability to withstand a variety of weather conditions. For example, a 500 kV line is designed as a high security line.

Such a line is designed to withstand what is considered a 50-year return storm. Under a 50-year return wind or 50-year return ice condition, the line is strained close to its

TABLE 3.1.3-2

TOWER DESIGN LOADS

	Security Classification			
	A	B	C	D
Wind on conductor (lbs/ft^2)	30	24	17	13
Wind on tower (lbs/ft^2)	86	65	52	42
Wind velocity (mph)	115	100	90	80
Reduction Factor (α)	.8	.8	.7	.7
Ice alone (radial in.)	2	2	1	3/4
Combined ice, wind				
(ice (in.)	1	3/4	1/2	1/4
wind (lbs/ft^2)	10	10	10	10
wind velocity (mph)	60	60	60	60
α	.9	.9	.9	.9

Longitudinal loads

crossarm	EDS all pts. or Loaded 1 pt.	EDS, 1 pt.	60% EDS, 1 pt.
ground cable arm	Loaded, 2 pts.	Loaded, 1pt.	EDS, 1 pt.

EDS = Everyday stress
α = wind gust reduction Factor
pts = points of support

TAKEN FROM APPENDIX "A"
C.S.A. STANDARD C22.3
NO. 1

LOADING AREAS
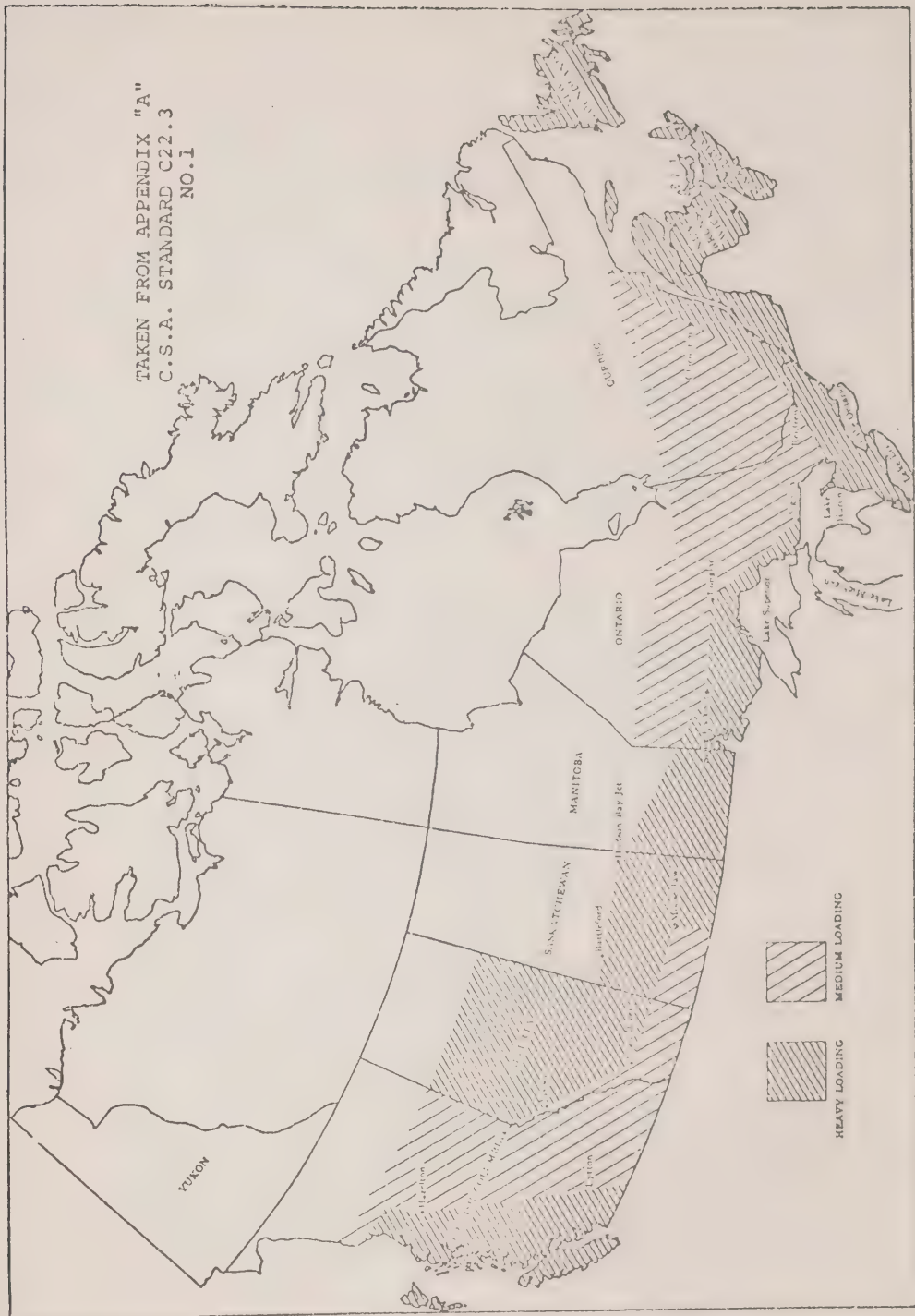
FIGURE 3.1.3 - 5

ultimate capacity. Under these conditions, some line components may need to be replaced because of permanent distortion due to excessive stress. A line is required to withstand without permanent distortion of components, a 20 to 30 year return storm.

(b) Vertical and Transverse Loads

Although ice usually forms on a complete tower span, severe winds are gusty, that is, they have a limited front. On long spans appropriate to high voltage line design, a gust reduction factor (2) is applicable. That is, the maximum gust velocity recorded at meteorological stations is reduced by a factor to account for its non-uniformity. This gust factor varies with the magnitude of the wind velocity.

(c) Longitudinal Loads

Longitudinal loading is usually designed into a tower. The purpose of this load is to accommodate uneven conductor tension loads resulting from uneven wind loading and uneven ice loading which results when ice falls from one span before falling from the adjacent span. Longitudinal capacity in a structure is designed to limit the extent of failure (i.e. number of structures affected) where a catastrophe such as impact by aircraft or a tornado causes a tower to fail.

3.1.3.4   Clearances

National standards (the Canadian Electrical Code, Part III, CSA Standard C22.3 No. 1) define minimum acceptable clearances for safe and continuous operation and protection of property.

Ontario Hydro normally provides a margin of clearance over these code requirements to ensure meeting the standard. Table 3.1.3-3 compares the vertical clearances of conductors above ground required by CSA C22.3 No. 1 and those provided by Ontario Hydro. Table 3.1.3-4 compares the horizontal clearances from conductors to a building required by CSA to the minimum provided by Ontario

Hydro. Both horizontal clearances are to be maintained when the conductor is swung due to wind. The swing calculations employed by CSA and Ontario Hydro are identical and the clearances are based on estimated transient voltages generated by switching operation.

Consideration is also given by Ontario Hydro to conductor swings that are possible during extremely high winds. Since conductor sag increases with tower span length, the conductor swing also increases, so that lines with long spans require a greater width of right of way than those with short spans.

In June, 1974, a study was conducted to review the adequacy of the clearances provided over farmland (3). Data and dimensions of farm equipment were obtained from the principal manufacturers of the largest equipment and opinions were sought from equipment dealers' associations. It was found that the minimum clearances required by the Canadian Electrical Code and provided by Ontario Hydro allow for vehicle heights of 13 feet 6 inches and permit the largest combines and other equipment engaged in such operations as plowing, cultivating, seeding, crop gathering and spraying to pass under the line at the lowest point of the conductor at it's maximum sag.

However, equipment such as chisel plows and disk harrows can be as high as 22 feet in the folded-up or transport position. The Canadian Electrical Code does not consider it necessary from a safety standpoint to provide mid-span minimum clearances above ground for equipment which folds vertically for transport. Such equipment in the folded-up position can easily pass under the line at other points of the span closer to a supporting tower.

TABLE 3.1.3-3

Comparison of Vertical Clearances

	230 kV		500 kV	
	CSA require -ment	Ont. Hydro Design Clearance	CSA require -ment	Ont. Hydro Design Clearance
Over land normally traversed by pedestrians only	15'-0"	18'-0"	20'-7"	25'-0"
Over roads and lanes	20'-0"	24'-0"	36'-5"	40'-0" *
Over farm lands and lands (other than roads) accessible to vehicles but not normally traversed by large transport trucks.	20'-0"	24'-0"	31'-2"	40'-0" **

*Ontario Hydro's design practice is to provide a minimum 50 foot clearance over roads because of the need to cross over local service lines.

** Over agricultural lands, a minimum of 40 feet is provided to reduce electrostatic effects.

TABLE 3.1.3-4

COMPARISON OF HORIZONTAL CLEARANCES

	230 kV		500 kV	
	CSA require -ment	Ont. Hydro Design Clearance	CSA require -ment	Ont. Hydro Design Clearance
Horizontal clearance to a readily accessible point or surface of a building	9.2'	11'	14.9'	17'

3.1.3.5   Right of Way Widths

Typical right of way widths are shown in Figures
3.1.3-6, 3.1.3-7, 3.1.3-8 and 3.1.3-9 for various
230 kV and 500 kV configurations. Widths for 765 kV
lines are shown for comparison purposes. The actual
widths required for specific rights of way vary,
depending on a variety of factors such as span
length, conductor size and sag and helicopter
requirements.

3.1.3.6   Line Design -- Relationship of Span, Tower Height
and Width of Right of Way

There are general relationships that exist between
tower height, span length and width of right of way.
For example, for a given conductor tension, the
longer the span, the fewer the towers but the towers
are higher and the right of way is usually wider
because of the increased conductor sag and resulting
swing out under wind pressure.

The components of a transmission line such as the
structures, foundations, insulation, hardware,
grounding and skywires have a single purpose - to
support and protect the line conductors which carry
electric power from one point to another. However,
line design is a complex process involving the
locating of structures on a given route so as to
utilize as fully as possible the design capacity of
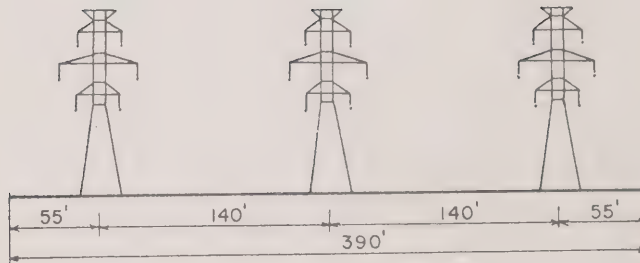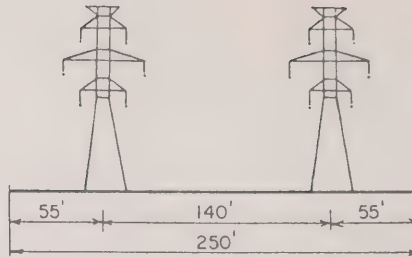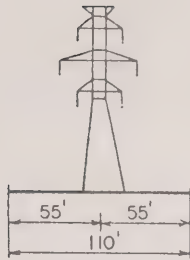
230kV 2-CCT TOWERS
RIGHT OF WAY WIDTHS

FIGURE 3.1.3-6
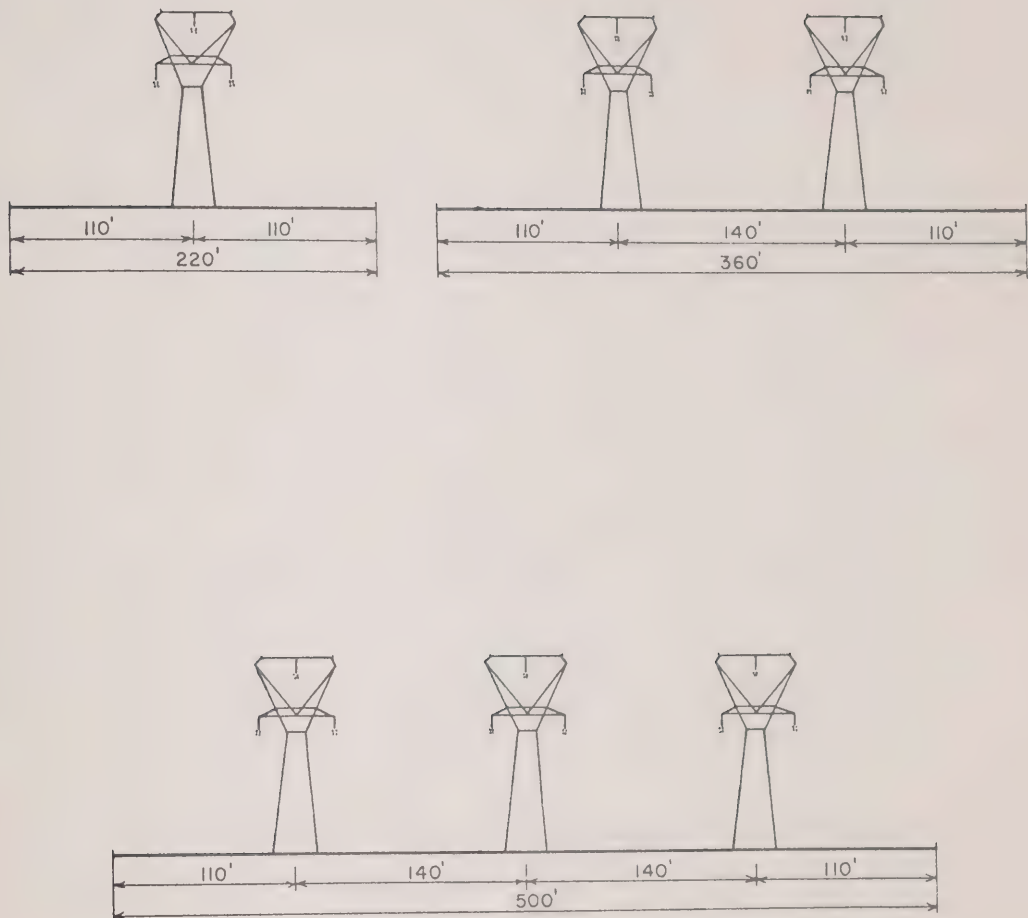
500kV 1-CCT TOWERS
RIGHT OF WAY WIDTHS

FIGURE 3.1.3-7
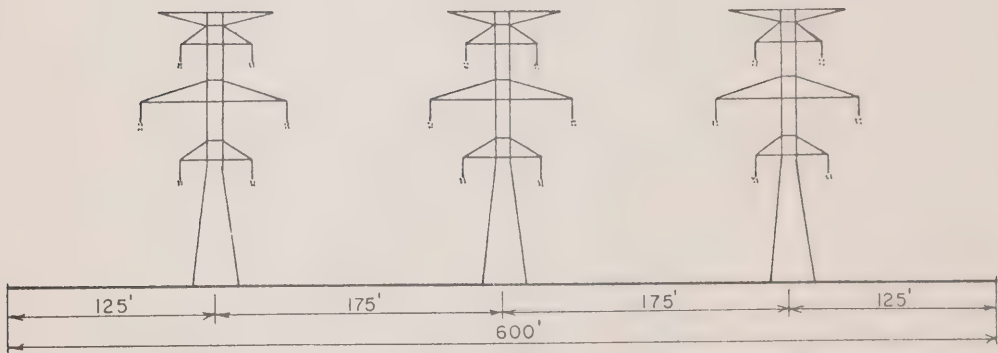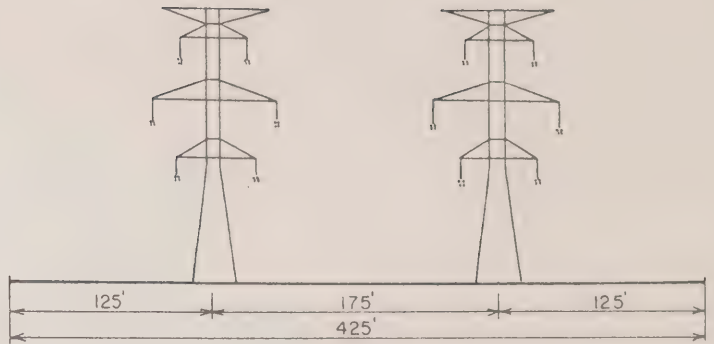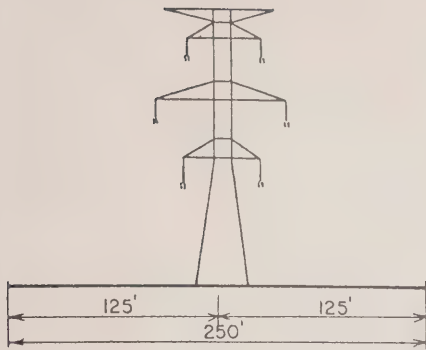
500kV 2-CCT TOWERS
RIGHT OF WAY WIDTHS

FIGURE 3.1.3-8

155'   155'
310'

155'   200'   155'
510'
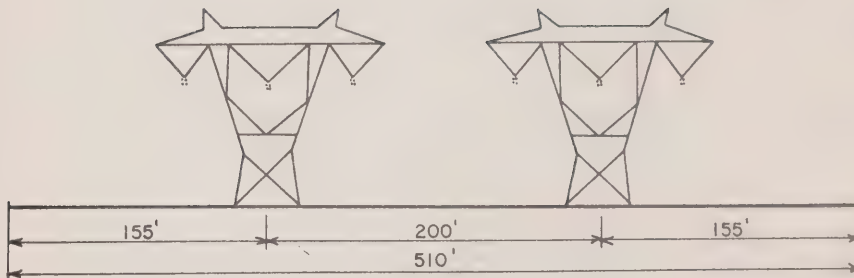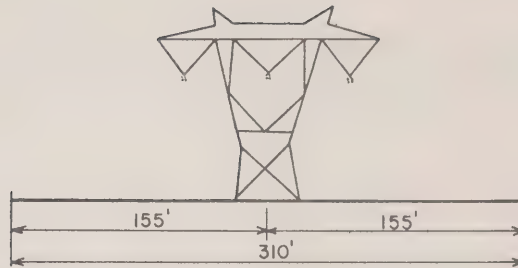
765kV 1-CCT RIGID TYPE TOWERS
RIGHT OF WAY WIDTHS

FIGURE 3.1.3-9

the components within the design, safety and
environmental restraints and to meet the required
levels of system reliability.

3.1.3.7 <u>Upgrading of Existing Lines or Rights of Way</u>

Several methods for improving transmission
facilities are examined before a decision is made to
build new transmission lines on new rights of way.
In order of ascending initial cost these are:

- Increasing the current carrying capacity at the
  same voltage.

- Increasing the operating voltage, but retaining
  existing towers and conductors.

- Increasing the operating voltage and current
  carrying capacity, using existing towers with
  new conductors.

- Removing existing towers and conductors and
  building new lines on existing rights of way.

(a) <u>Increased Current Capacity</u>

When current is increased, the temperature of a
conductor increases. The higher temperature
causes longitudinal expansion and results in
more sag with a consequent reduction in ground
clearances.

Ground clearances can be improved by increasing
conductor tension, by interspacing structures
or by adding tower extensions below the
existing structures.

Any combination of these methods may be used,
but they are not always feasible. Any increase
in conductor tension, for instance, increases
the stress on angle and anchor towers and also
reduces the conductors' capacity to carry ice
and wind loads. Interspacing of structures is
a relatively costly alternative and may require
additional property rights.

(b) <u>Increased Line Voltage</u>

Increasing the voltage of a line designed for a
lower voltage level requires re-insulation and
results in a reduction of the normal clearances
for the higher voltage level with a consequent
reduction in the security level.

Another consideration is the increased radio
noise caused by higher conductor surface
voltage gradient. The voltage gradient is a
function of voltage, conductor diameter and
phase spacing. As most 115 kV lines are strung
with smaller conductors than 230 kV lines and
as phase spacing is also less, it follows that
115 kV lines will generate more radio noise if
they are converted to 230 kV operation. In
areas where signal strengths are high, the
signal-to-noise ratio may still be good enough
to provide satisfactory radio reception.
Conversely, in areas with relatively weak
signals, receivers close to the lines may not
have satisfactory reception.

(c) <u>New Conductors on Existing Towers</u>

It is possible in some cases to install larger
conductors on existing towers and so improve
current carrying capacity and, in some cases,
permit an increase in voltage. As larger
conductors impose greater structural loads it
is necessary to carry out a complete structural
analysis to ensure that the towers will not be
overloaded. This alternative is rarely
feasible, and even in those cases where it can
be done some reduction in line security must be
accepted. It is normally not possible to
convert existing 230 kV lines to 500 kV
operation.

(d) <u>New Lines on Existing Rights of Way</u>

Frequently, existing rights of way can be
rebuilt with lines of higher voltage. However,
in many cases this is not possible unless an
alternative facility to replace existing lines
is available to take the place of the lines
which must be removed; otherwise the supply to

3.1-23

some customers would be either cut off or the security of supply drastically reduced.

To rebuild to higher voltages also implies that the rights of way are wide enough to accommodate all the new lines while meeting all the criteria encompassing safety and environmental acceptability. It is usually not possible to simply convert the rights of way from 115 kV or 230 kV to 500 kV construction since the higher voltage line would require a wider right of way and, in many instances, buildings have been erected near the edge of the right of way.

References

(1)   Meteorological Evaluation of the Proposed 500 kV Transmission Line Route Area Between the Bruce Generating Station and the Toronto – Hamilton Region, Meteorology Research Inc. – Report MRI 74FR-1284.

(2)   Wind Loads on Overhead Lines – A.P. Birjulin, V.V. Burgsdorf, B.J. Makhlin, CIGRE 1960-225.

(3)   Report on Height Limitation of Lines on Farmland, B.R. Murphy, June 1974.

1 3.1.4   AC UNDERGROUND TRANSMISSION

2

3 3.1.4.1   General

4

5   Underground transmission lines require narrower
6   rights of way than overhead lines. They elimate
7   much of the visual effect on the environment. They
8   are, however, very costly.

9

10   Where such installations are undertaken, Ontario
11   Hydro uses, primarily, two types of cable at
12   transmission voltages of 115 kV and 230 kV. Self-
13   contained low pressure, oil-filled (LPOF) operate in
14   the 15 to 75 psi range and high-pressure oil-filled
15   pipe-type (HPOF) operate at about 200 psi. Both
16   consist of a conductor insulated with oil-
17   impregnated paper, pressurized with oil to exclude
18   air and moisture.

19

20   With regard to 500 kV cables, after two and one-half
21   days of expert testimony, the Solandt Commission
22   concluded, (1) that

23

24   "500 kV underground cable is not at present an
25   attractive alternative and that neither the
26   cost nor the security risks are justified by
27   the improvement in environmental impact that
28   would be achieved".

29

30   A major factor limiting the power transmitting
31   capability of ac underground transmission is the
32   ability of the cable to dissipate heat generated by
33   the flow of electric current. Heat from an overhead
34   line is easily dissipated directly into the
35   atmosphere by radiation and convection. In
36   underground cables, the heat must flow through the
37   cable insulation and the surrounding earth, both of
38   which act as effective thermal insulations. As a
39   result, the conductor temperature of an underground
40   cable tends to be higher than for an overhead line.
41   The temperature rise must be limited to prevent
42   degredation of the cable insulation. Because of
43   this, it is the maximum permissible temperature of
44   the insulation that usually limits the allowable
45   maximum current.

46

47

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51   3.1-25

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55

A cable acts as a capacitor with the conductor and insulator shielding as the electrodes. The insulation is not a perfect dielectric so that there is additional heat generated due to dielectric losses. These increase as the system voltage increases. For 115 kV cables, these losses are about one-tenth the total permissible losses whereas, at 500 kV, they account for about one-half.

Because of the high capacitance of an ac cable, a major factor limiting the distance of ac underground transmission is the large quantity of charging current which reduces the amount of current available for active power. The magnitude of charging current increases with cable length and there is a critical length at which no active power is available. For a 500 kV oil-impregnated paper insulated ac cable, the theoretical critical length is in the 20 to 30 mile range. In practice, devices to overcome this problem, called shunt reactors, would be required when the line length is greater than about one-half the critical length. Although capacitive current can be compensated by installing shunt reactors at intervals along the route, these reactor stations are complex and costly and reduce the reliability of a cable installation.

Although the probability of an outage on an underground cable is smaller than for an overhead line, should an outage occur it is likely that the cable would be unavailable for service for a longer period. For some applications, it may be necessary to allow for this unavailability and build additional spare capacity into the underground cable circuits. This would require wider rights of way than those shown in Figures 3.1.4-1 and 3.1.4-2.

3.1.4.2   Cable Types

(a)   Self-Contained, Low Pressure Oil Filled Cable
       (LPOF Cable)

These cables are sheathed individually in the factory with either an aluminum or lead sheath and covered with an extruded plastic jacket for corrosion protection. Because they are self-contained they can be laid with wide separation

3.1-26

between phases to improve heat dissipation and
so increase current carrying capacity.

Their disadvantage is that usually almost a
mile of trench must be opened at one time for
cable laying. The sequence of installation is
such that cable is laid from joint bay to joint
bay while the previous section is being back-
filled and the next section is being excavated.
Because of interruption to streets and traffic,
this system is not generally used in city
streets.

(b) High-Pressure Oil-Filled Pipe-Type Cable
     (HPOF Cable)

These cables are shipped from the factory with
a moisture barrier, but without a metallic
sheath, on reels sealed with a plastic sheet
and slightly pressurized with nitrogen to
exclude air and moisture. Three cables forming
one circuit are pulled together into one pipe.

As the pipe can be installed well in advance of
cable pulling, it is only necessary to open a
few hundred feet of trench at one time, and
consequently there is relatively little
interruption to traffic. The strong steel pipe
provides mechanical protection from dig-ins.
However, since three cables are close together
in the pipe mutual heating effects are more
pronounced than with self-contained cables.
Furthermore, the additional losses in the cable
shield and the pipe require a larger conductor
for the same current carrying capacity. As a
result pipe-type cables cost more than self-
contained low-pressure oil-filled cables for
equivalent current carrying capacity where the
low pressure type can be directly buried (i.e.
off city streets)

(c) Compressed Gas Insulated Cable

Gas insulated transmission systems have been
installed in recent years at voltage levels up
to 500 kV but Ontario Hydro has not yet
installed any. Generally each phase of these
gas insulated systems consist of two concentric

metal tubes, one the conductor and the other
the sheath, and these are held apart by solid
insulating spacers. The insulating medium used
so far is sulphur hexafluoride (SF6), usually
at pressures in the order of 30-50 psig.

All installations to date are short, and total
service experience is short. The IEEE
Insulated Conductor Committee Listing of Cables
shows ten compressed gas insulated cable
installations in North America, totalling less
than one mile, at the end of 1973. The first
system was energized in 1971.

The major advantages of compressed gas
insulated cables, compared with paper insulated
cables, are longer critical length because of
lower capacitance, lower termination costs and
higher power ratings. However, because factory
produced lengths are so short, many field made
joints are required and these must be made
under very clean conditions. As line lengths
increase, the advantages due to lower
termination costs are overcome by higher cable
costs.

3.1.4.3   Comparison of Overhead with Underground

The two underground arrangements shown in Figure
3.1.4-1 are equivalent to one 2-circuit 230 kV
overhead line with a single 1843 kcmil conductor per
phase. The LPOF cable requires two 1500 kcmil
copper conductors per phase and the HPOF cable
requires two 2750 kcmil copper conductors per phase.
The estimated installed cost for the overhead line
is $300,000 per mile based on 1976 costs. This
compares with an estimated installed cost for the
LPOF cable of $3,400,000 per mile and $6,400,000 per
mile for the HPOF cable. These cable costs do not
include facilities at the termination such as oil
pressurizing equipment.

The above LPOF cable installation costs only apply
to installations in rural and suburban areas. The
installation of LPOF cables in congested areas
normally involves the use of ducts and manholes to
reduce the length of trench that must be opened at

L.P.O.F. CABLE
2 x 1500 KCMIL COPPER CONDUCTORS/PHASE

H.P.O.F. CABLE
2 x 2750 KCMIL COPPER CONDUCTORS/PHASE

GRADE

14'

TWO CIRCUITS

50'

GRADE

12.5'

TWO CIRCUITS

45'

OUTLINE OF TRENCH

REINFORCED
CONCRETE
PROTECTION SLAB
AND SIDEWALLS

R W B   R W B
10" 10"   10" 10"

4'

4.5'

4'

7'

TYPICAL TRENCH

OUTLINE OF TRENCH

COMPACTED
GRADED
BACKFILL

1.5'

2'

4'

5'

4.2'

TYPICAL TRENCH
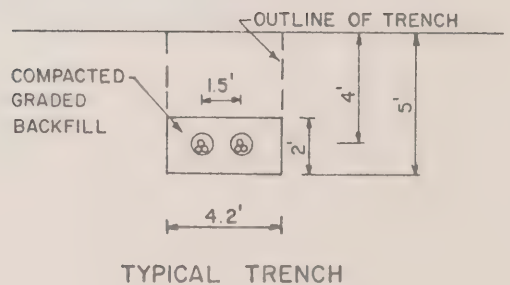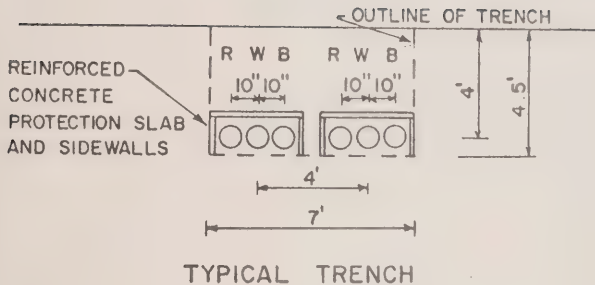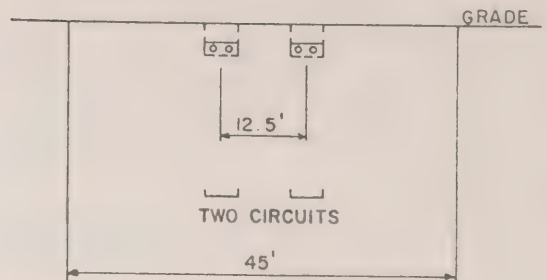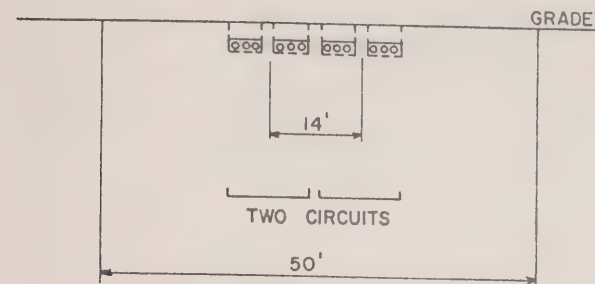
230kV UNDERGROUND CABLE
RIGHT OF WAY WIDTHS

FIGURE 3.1.4-1

any one time. This would result in costs close to
those shown for an HPOF installation.

Figure 3.1.4-2 shows the right of way width required
to install two 500 kV LPOF cable circuits equivalent
to a 2-circuit 500 kV overhead lines. The
underground cable circuits require three 3800 kcmil
conductors per phase and the overhead lines would
require a 4-conductor bundle of 585 kcmil conductors
per phase.

The estimated cost of the underground line is
$16,000,000 per mile compared to $600,000 for the
overhead line.

Because of the larger number of conductors per phase
required for HPOF cable, it is considered less
desirable than other types.

Tables 3.1.4-1 and 3.1.4-2 compare the amounts of
material required to install the 230 kV and 500 kV
underground and overhead lines described above.

As noted in the tables, large amounts of excavation,
installation of concrete and provision of special
backfill are required for underground construction.

3.1-29

L.P.O.F CABLE
3 x 3800 KCMIL COPPER CONDUCTORS / PHASE

TWO CIRCUITS
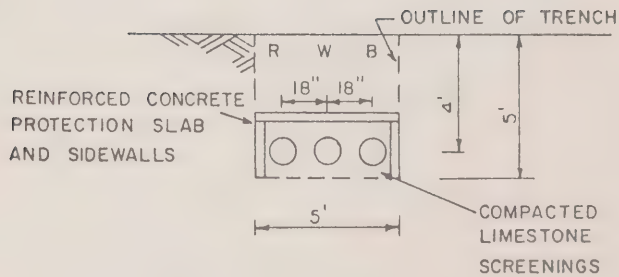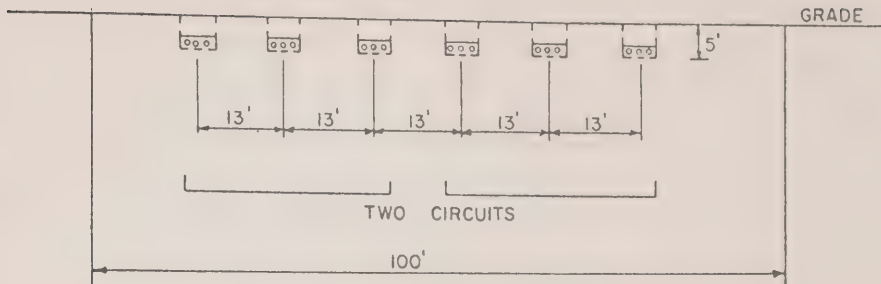
TYPICAL TRENCH

500 kV UNDERGROUND CABLE
RIGHT OF WAY WIDTHS

FIGURE 3.1. 4-2

TABLE 3.1.4-1

Comparison of Materials
Overhead vs Underground
Based on 2-cct 230 kV (1 mile)

Material	Overhead Line	Underground Cable	
		LPOF	HPOF
Steel	56 tons (tower, reinforcing in foundation)	None	233 tons(pipe)
Copper	None	147 tons(cond.)	296 tons(cond.)
Aluminum	32 tons(cond. including core)	41 tons(sheath)	None
Porcelain	4 tons(insul.)	None	None
Paper	None	59 tons(insul.)	63 tons(insul.)
Oil	None	10,000 Imp. gals. (insul.)	33,250 Imp. gals. (insul.)
Plastic	None	16 tons(sheath insul.)	None
Brass	None	None	26 tons (protective assembly)
Special Backfill	None	3500 cubic yds.	3000 cubic yds.
Concrete	171 cubic yds.	1110 cubic yds.	None
Excavation	171 cubic yds.	12600 cubic yds.	8600 cubic yds.

Cond. = conductor, insul. = insulation, yds. = yards

Total Weight of Material			
Material Installed	442 tons	8458 tons	5866 tons
Material Removed	230 tons	6350 tons	4620 tons
Material Excavated	230 tons	17000 tons	11600 tons

Table 3.1.4-2

Comparison of Materials
Overhead Line vs Underground Cable
(for 1 mile of 2-cct, 500 kV construction)

Material	Overhead Line	Underground LPOF Cable
Steel	187 tons (steel and concrete reinforcing)	None
Copper	None	557 tons (conductor)
Aluminum	57 tons (conductor, includes steel)	108 tons (Sheath)
Porcelain	7 tons (Insulation)	
Paper	None	238 tons (Insulation)
Oil	None	44000 Imp. gals (Insul.)
Plastic	None	59 tons (Sheath Insul.)
Special Backfill	None	8560 cubic yards
Concrete	544 cubic yards	2000 cubic yards
Excavation	544 cubic yards	24500 cubic yards

Total Weight of Material		
Material Installed	1351 tons	19712 tons
Material Removed	735 tons	15200 tons
Material Excavated	735 tons	33000 tons

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3.1.5   STATUS OF HVDC SYSTEMS

High Voltage Direct Current systems (HVDC) involve
the conversion of a high voltage alternating current
power supply to direct current by rectifiers, and
the subsequent conversion of the direct current
power by inverters to alternating current – both
conversions being at the same nominal voltage.
Transformation of the ac power is required at the
supply end of the HVDC system to match the ac supply
voltage to the selected voltage level of the dc
system. Transformation is similarly required at the
receiving end to match the inverted ac power to the
three-phase voltage of the receiving ac system.

The successful application of the Thyristor, a solid
state rectifier of alternating current, in the early
1970's to HVDC installations, has increased interest
in HVDC transmission by designers of electric power
systems. The thyristor removed a number of
limitations on performance and reliability
associated with the mercury arc rectifier.

HVDC systems have some characteristics that are an
advantage for power transfer systems. The major
advantages are:

(a)   Charging current problems on underground or
       underwater cables are eliminated, thus
       permitting transfer of large blocks of power
       over longer distances by insulated cable. This
       is of particular advantage for crossing wide
       bodies of water. An example is the Vancouver
       Island 260kV HVDC Submarine Link.

(b)   DC transmission permits the interconnection of
       neighboring systems without the need for them
       to be in synchronism.

(c)   The transmission of large blocks of power over
       very long distances may be more economical by
       HVDC than by EHV overhead systems of equivalent
       capacity due to reduced costs of the HVDC
       transmission line. An example is the Nelson
       River Project in Manitoba. A dc line can be
       expected to cost about seventy to eighty
       percent of the cost of an ac line of comparable
       capacity.

A single circuit ac line has three phases and
the normal practice is to use two skywires,
whereas a bipolar dc line would have two poles
(positive and negative) and usually a single
skywire. Thus the towers for a dc line must
provide only three points of wire attachment,
as compared to five points for a single circuit
ac structure (See Figure 3.1.5-1).

The insulation requirements for a dc
transmission line are less severe than for an
ac line. The most important requirement of
HVDC line insulation is the capability of the
insulator string to withstand continuously the
normal operating voltage, rather than switching
surges. This capability is determined by the
leakage distance of the insulator units, with
special units with long leakage distances
having been developed for dc lines. These
special units permit use of shorter insulator
strings than could be used on an ac line having
the same nominal operating voltage.

The smaller number of wire support points and
decreased insulation requirements for dc
transmission lines results in smaller, lighter
towers and decreased right-of-way requirements
as compared to equivalent ac lines. Figure
3.1.5-1 shows a comparison between a 500kV ac
structure and a ±450 kV dc structure.

Other minor advantages of HVDC systems are:

- The HVDC system does not add to the fault
  levels of existing installations. This is one
  of a number of reasons quoted for the adoption
  of HVDC for the supply of power to the City of
  London, England at Kingsnorth.

- The smaller towers reduce the visual effect of
  the line. Also, radio interference and audible
  noise are reduced.

- There is the possible increased availability of
  the line by operating with only one pole and an
  earth return. This mode of operation would
  normally be used only in an emergency.
  Prolonged operation in the unipolar mode is

79'-7"

152'- 0"

45'- 0"
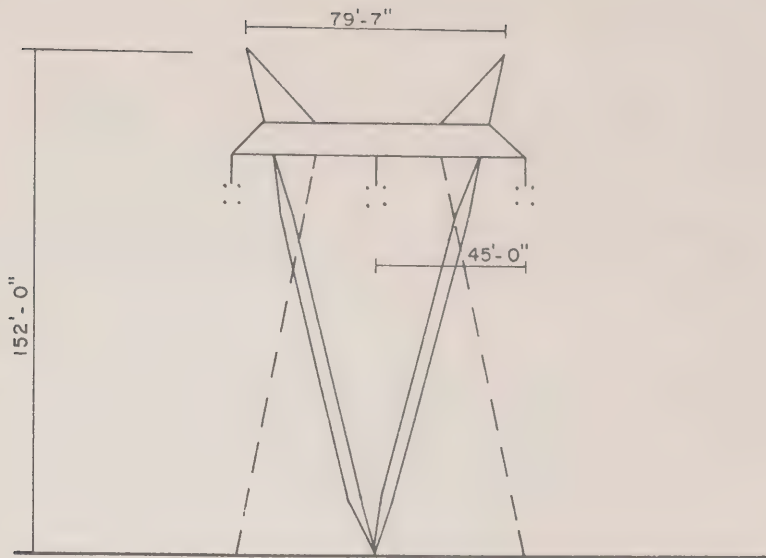
500kV 1-CCT AC
GUYED HORIZONTAL

44'- 0"

101'- 0"
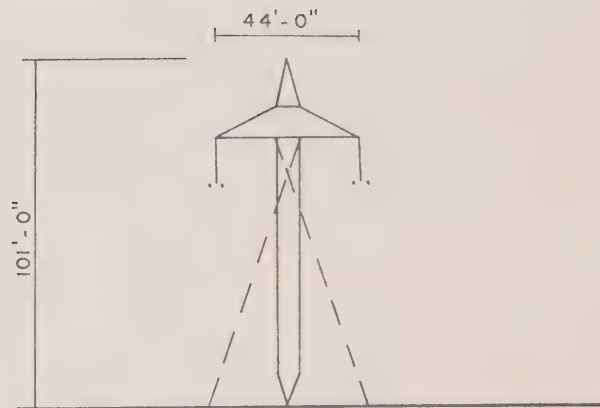
±450kV 2-POLE DC
GUYED HORIZONTAL

FIGURE 3.1.5-1

1	avoided due to problems of nearby pipe lines,
2	ground electrodes and interference with railway
3	signal systems.
4	
5	The characteristics of HVDC systems also impose a
6	number of constraints to their application. The
7	more important of these are discussed below.

3.1.5.1   Reliability

(a)   The rectifiers, inverters, harmonic suppressors
and the voltage and power factor control
equipment at the terminal stations add to the
complexity of the system, compared to an ac
system, with a consequent reduction in
reliability.

(b)   The basic unit of a HVDC system is the
converter with its electronically controlled
high power valve. Two converter stations are
required, one to change from ac to dc, and the
other to change from dc to ac. The converter
must respond to control requirements within a
fraction of a cycle of the power system
frequency. Though hundreds of miles apart, the
inverter and rectifier must be co-ordinated for
stable operation. This leads to high speed
control loops involving electronic circuitry
for control, protection and communications.
The total electronic circuitry associated with
HVDC systems becomes very complex and involves
many components. This complex electronic
system results in numerous short duration power
interruptions.

3.1.5.2   Line Tapping

Most HVDC systems have only been designed for the
point-to-point transfer of power. It has not been
practical to tap the dc line for the supply of power
to intermediate points. Each tap would have the
drawback of adding substantially to the complexity
of the system. Much work has been done on the
development of a dc circuit breaker and some success
is now being reported by manufacturers. Compared to
equivalent ac breakers, they will be a complex
device. Some time will still be required to
evaluate the capability of the equipment to perform

3.1-35

in a working installation. A reliable dc circuit breaker may solve some of the problems associated with intermediate taps.

3.1.5.3 <u>Interference Effects</u>

Special precautions have to be taken to mitigate the following effects:

(a) Interference with railway signal systems during transient conditions on the HVDC system - particularly unipolar operation.

(b) Electrolytic effect on pipelines and other underground plant due to unipolar operation of the transmission line, unless special precautions are taken.

(c) Telephone interference due to harmonics on the dc and ac lines created by the rectifier and inverter.

3.1.5.4 <u>Cost</u>

The cost of installed terminal equipment for a two-terminal 1,000 MW HVDC installation has been estimated to be in the range of $60 to $100 per kW at 1975 prices. The cost of the equivalent terminations for a 500kV ac line is estimated at 5 to 6,000,000 dollars. The additional cost of HVDC terminals must be saved on the cost of the transmission line, or justified by other advantages, if the installation is to be viable.

Ontario Hydro has studied and continues to study possible applications of HVDC on its system as an alternative to EHV ac. To date, these studies have not shown economic advantages.

Related Material

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3.1.6   FUTURE CONCEPTS AND RESEARCH ON OVERHEAD LINES AND
         UNDERGROUND CABLES

3.1.6.1 Overhead Lines

(a) UHV

     The status and the research work on alternating
     current transmission lines at voltages above
     800 kV are described in Section 3.1.1.3.

(b) High Voltage and Extra High Voltage AC
     Lines

     While there are satisfactory solutions to the
     major problems in the design of reliable lines
     for operation at voltages between 115 kV and
     800 kV, work is continuing in a number of areas
     in order to make the best possible use of
     components.

     In conductor design, investigations are being
     carried out to operate acsr conductors at
     higher than presently accepted temperatures in
     order to increase their current carrying
     capacity.

     Research is continuing on a new type of damper
     as well as interphase spacers to suppress
     conductor galloping in order to reduce the
     required phase spacing of conductors.

     New types of insulators to overcome the effects
     of contamination on their resistance to
     electrical flashover have been under active
     study and experimentation for about 6 years. A
     new shape of insulator and more reliable semi-
     conducting glazes have been developed
     permitting shorter insulator strings and line
     compaction. A short 2-circuit prototype line
     incorporating this development has been
     completed.

     In line maintenance, full scale trials are
     underway to develop methods for live-line
     working of such lines.

Much of this work is being carried out under the Transmission Research Program described below.

(c) Transmission Research Program

For this Special program initiated in 1970 (1), new facilities were provided, including a fog chamber for artificial contamination testing, a test line for research on galloping control and an outdoor high voltage laboratory for surge and 60 Hz testing of full scale line structures up to the 500 kV operating voltage level.

Ontario Hydro is developing a compact 115 kV/138 kV subtransmission line for roadside installation. This work is being done on a research contract for the Canadian Electrical Association.

3.1.6.2 Underground Lines

(a) DAMUT and DIGUT Systems

A feasibility study on a Ducted Air Medium Underground Transmission (DAMUT) system for operation at 230 kV was initiated by Ontario Hydro in 1972. Very briefly stated, the circuit design is based upon the use of three 12-inch diameter aluminum tube conductors arranged in triangular configuration on approximately 3-foot centres and housed within a 9-foot diameter corrugated steel duct with air as the insulating medium.

Potential advantages are lower cost per kW of transmission capacity, higher capacity and simpler maintenance compared to conventional cables.

Prototype testing has been done on the main duct components but a further five to ten year period will be required for development of joints, conductor support insulators and terminations to produce a complete assembly for full electrical testing before possible subsequent use in the Hydro network.

Consideration also was given to the development
of a Ducted Inert Gas Underground Transmission
(DIGUT) System for operation at 500 kV using a
similar basic design but with an inert gas such
as SF6 as the insulating medium. However, no
laboratory tests have been conducted to date.

(b) Cryogenic Cable (Cryo-Resistive and
Superconducting)

There are two basic types of cable in which the
conductors operate at very low temperatures.
One is the cryo-resistive cable where
conductors are operated at the temperature of
liquid nitrogen, i.e., -169 C. The other is
the super-conducting cable which utilizes
exotic materials such as niobium, for the
conductor and operates at temperatures below -
250 C. Both systems require complex
refrigerating plants, which consume large
amounts of power.

Both systems are experimental and are not
likely to be available commercially before
1990. When available, they may lead to lower
costs of underground transmission, but only
when large blocks of power (several thousand MW
on a single circuit) are to be transmitted
continuously. To ensure reliability, it will
be necessary in a practical system to provide
some redundancy with the result that the cables
would not normally operate at their full load
rating.

Outage durations may be longer than with
conventional cable designs. It will take time
for the cable to warm to ambient temperature,
allowing repair or maintenance crews to work.
Before the cable is returned to service, it
will require a similar length of time to reduce
the system temperature to the operating
conditions.

Line
Number

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Line Number		
1	3.2	TRANSFORMER AND SWITCHING STATIONS

3.2 <u>TRANSFORMER AND SWITCHING STATIONS</u>

3.2.1 <u>INTRODUCTION</u>

Transformer and Switching Stations serve two essential functions in a power system. The stations interconnect transmission lines, transformers and subtransmission lines, and change voltages from one transmission level to another, or to a subtransmission level. Some utilities refer to these transformer and switching stations as substations, to separate them from the general term, stations, which they reserve for generating stations. The cost of these transformer and switching stations at the end of 1974 represented about 13% of Ontario Hydro's capital investment (1).

3.2.2 <u>VOLTAGE LEVELS</u>

Nominal transmission voltages switched and transformed range from 115 kV to 500 kV. Ontario Hydro's first 115 kV transmission system including transformer stations was energized September 4, 1910, to transmit power from Niagara Falls. The first 230 kV transmission system including Toronto Leaside Transformer Station was energized October 1, 1928, to supply energy to Toronto from ChatsFalls on the Ottawa River. The first 500 kV transformer stations were energized in 1966 to switch and transform power from the Moose River System. The increase in loads in the Province required these increases in voltage and in the transformer station capacities.

The voltage levels of transmission and subtransmission determine the required switching and transformation facilities for the associated stations. The voltage levels themselves are dictated by available technology, energy demands and distances from source to customer.

Areas are supplied out of transformer stations most commonly at subtransmission voltages of 44, 28.4 and 14.2 kV. Usually, the higher the voltage, the larger the geographical area served, for example, 44 kV in Georgian Bay and Eastern Ontario areas and 14.2 kV in dense city areas like Toronto, Hamilton and Ottawa.

1	3.2.3	### TYPICAL POWER DIAGRAMS

Transformer stations perform their major functions
of transformation and switching in switchyards
interconnected by transformers capable of
transforming the power demands from one voltage
level to another.

Figure 3.2.3-1 illustrates two typical substations
in Ontario Hydro's system. One station is a bulk
power switching and transformer station, with 500 kV
switching for eight line circuits and four
transformers. The 500/230 kV transformers take
energy from the 500 kV bulk power system and deliver
it to the 230 kV switchyard, with switching for four
transformers and eight 230 kV transmission circuits.
The smaller station on the right of figure 3.2.3-1,
an Area Supply Transformer Station, called a Dual
Element Spot Network (DESN) station, transforms
power from two 230 transmission circuits to supply
the adjoining area.

The number and configuration of circuit breakers and
switches and the configuration and physical
arrangement of buses have a significant effect on
the reliability, maintenance, cost and other
features of the switchyard (2).

Utility experience indicates that the incidence
transmission circuit faults exceeds that of
transformer faults by a substantial factor and
transformer faults are more numerous than bus faults
by a further substantial factor. The station is
designed to take into account these relative failure
rates. As a result, transmission circuits are
usually associated with one or two circuit breakers
so that they may be quickly separated from the
station when they fail. The terminating points for
each circuit of two circuit lines are separated in
the switchyard to reduce the probability of loss of
both circuits and also to reduce the impact on the
station if both circuits of a two circuit
transmission line are faulted. Disconnecting
switches are installed at the termination of each
circuit to isolate the circuit for sustained fault
conditions and repair or long term maintenance.
Buses, the most secure element in the Station, may
extend throughout the entire station (X,Y) or may

TYPICAL STATION SINGLE LINE (POWER FLOW) DIAGRAMS.

LEGEND

— BUS (THREE CONDUCTORS)

╱ SWITCH

✕ CIRCUIT BREAKER

⧢ TRANSFORMER

⊥ CAPACITOR

CIRCUIT R
CIRCUIT S

TO OTHER AREA SUPPLY STATIONS AND POSSIBLY ANOTHER BULK POWER STATION.

28 OR 44 KV

AREA SUPPLY STATION (A.E.S.N.)

500 KV

230 KV
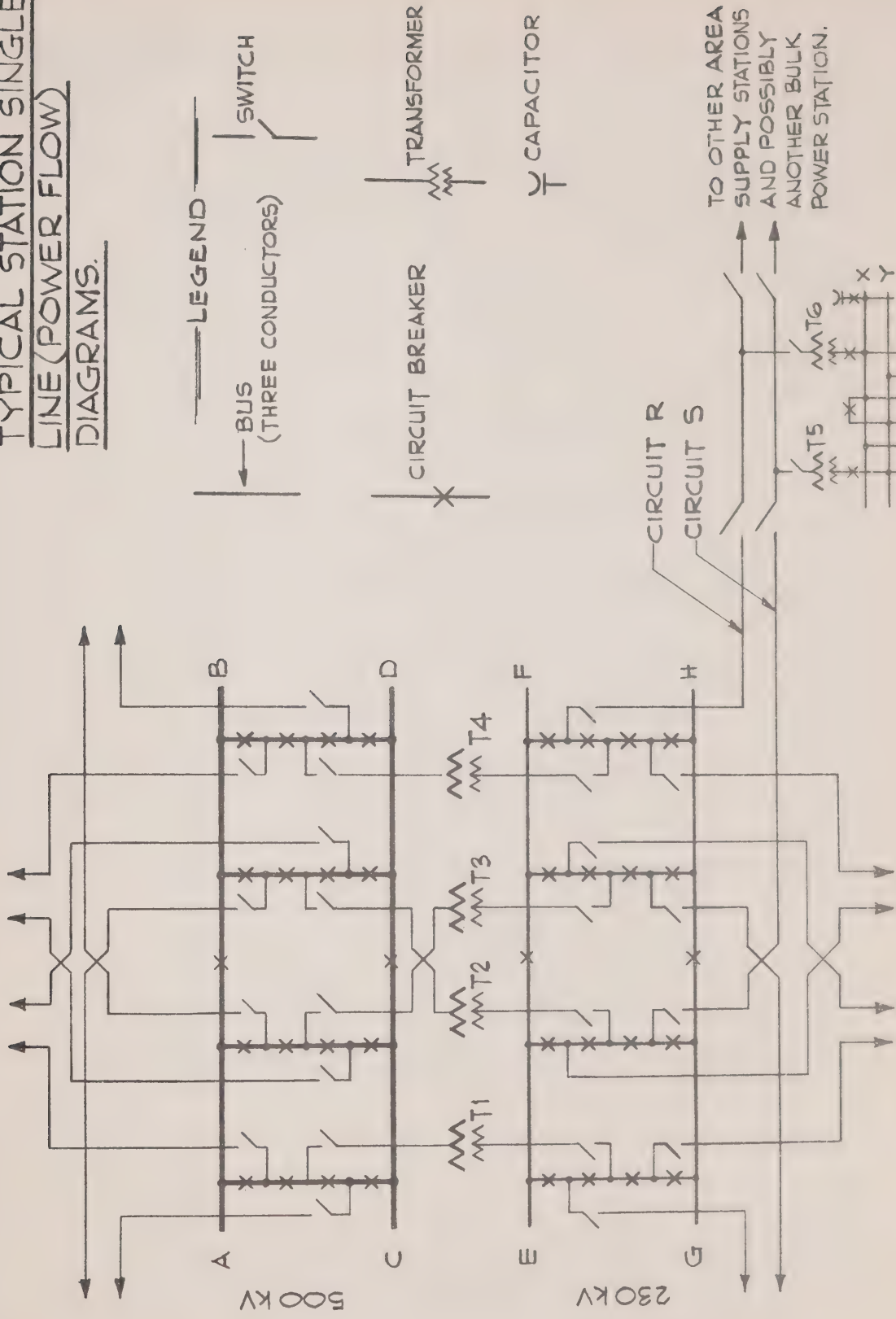
BULK POWER SWITCHING AND REGIONAL SUPPLY STATION

1 have sectionalizing locations in them (AB,CD,EF and
2 GH). Transformers, may be fully isolated by circuit
3 breakers as in the bulk power station or connected
4 directly to the transmission circuits (R&S) as in
5 the area station. Each circuit of the two circuit
6 transmission line, with its associated transformers
7 may carry overloads, with reduced line efficiency or
8 accelerated loss of transformer insulation life.
9 This situation may develop in emergencies, when its
10 parallel elements are out of service. This overload
11 capability is used, for example, in the Area
12 Stations (DESNs) where either transformer (T5 or
13 T6), with the incorporation of special oil
14 circulating pumps and radiator fans, can carry its
15 own load and most of the load of its companion unit
16 in emergencies. This provides reliable service
17 without the need for expensive 230 kV circuit
18 breakers in the area supply stations. Stations are
19 also designed to operate to their full capacity
20 during routine and emergency maintenance activities.
21 This is achieved with switches on either side of all
22 circuit breakers and transformers to allow for their
23 isolation while maintenance takes place.
24 Examination of Figure 3.2.3-1 will show that any 500
25 or 230 kV circuit breaker or any transformer may be
26 removed from service with the rest of the station
27 remaining interconnected. A special switch, between
28 28 or 44 kV circuits in area stations, is provided
29 so that a circuit breaker may switch two
30 subtransmission circuits while the adjacent circuit
31 breaker is being maintained or repaired.

32 The methods described above provide adequate
33 reliability and provision for maintenance without
34 incorporating more conservative and costlier types
35 of switching diagrams, such as the conservative
36 double bus, two breaker per element design which
37 would require approximately four additional 500 kV
38 circuit breakers, four additional 230 kV circuit
39 breakers and 10 additional 28 or 44 kV circuit
40 breakers in Figure 3.2.3-1. The costs for any
41 switchyard will generally vary directly as the
42 number of circuit breakers. (3)
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47
48
49
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51   3.2-3
52
53
54
55

1 3.2.4 STATION SITES AND LAYOUTS

3   The land area available for a station site, the soil
4   conditions and the use of adjacent lands have a most
5   significant effect on the station's design. The
6   required size of transformer station sites vary from
7   0.5 acres for an urban indoor 115 kV station, 8.7
8   acres for typical DESN station in suburban areas, 60
9   acres for a major 500 kV gas insulated switchgear
10   station to 400 acres for a major 500 kV open bus
11   station.

13   In commercial or residential urban areas, new
14   stations will most probably be enclosed in
15   buildings. To the extent practicable, the building
16   is architecturally treated to blend with adjacent
17   buildings. In suburban industrial and rural areas,
18   open switching on steel structures will most
19   probably be selected for 115 and 230 kV stations.
20   If a large enough site is not available, a gas
21   insulated switchgear design may be selected.

23   As noted above, the area required to accommodate a
24   500 kV transformer and switching station will vary
25   from about 60 to 400 acres including an allowance
26   for landscaping. The 60 acre size is based on the
27   use of compact gas insulated switching equipment.
28   Although Ontario Hydro has confidence in this type
29   of 500 kV switchgear, there are not yet any
30   installations in the world of the size and voltage
31   of the equipment purchased for the Claireville and
32   Milton transformer stations. Accordingly, its
33   further use at 500 kV or at a higher voltage will be
34   contingent on successful operating experience being
35   gained, as well as other factors such as future
36   costs and availability.

37   Most new stations incorporating open switching will
38   be of the low profile rigid bus design, Figure
39   3.2.4-1. (4) This design involves the use of solid
40   tubular structures 50 feet high for 500 kV and 29
41   feet high for 230 kV. Most existing stations are of
42   the high profile strain bus design which are 96 foot
43   high lattice steel structures at 500 kV and 52 foot
44   high lattice steel structures for 230 kV, Figure
45   3.2.4-2. The 96 foot height makes the 500 kV
46   switchyards imposing when seen from close up and
47   readily visible on the horizon since they are not

FIGURE
3.2.4-1

FIGURE
3.2.4-2

screened by the average wood lot in Southern Ontario which is 50 to 70 foot in height, Figure 3.2.4-3. The lower height of the low profile bus design should permit effective screening of the station structures by landscaping using earth mounds and trees. An area 50 to 200 feet wide around the perimeter of the site is acquired where possible for this purpose.

Confusing configurations and arrays of equipment and controls can lead to operating errors and therefore must be avoided. Station switchyards and associated buildings are designed with equipment and buswork arranged in straight forward configurations with spacing to provide for the maximum safety of operating personnel. Adequate clearances are maintained to live parts. Walkways, both indoors and outdoors, are designed with alternative means of approach and escape. All stations where the facilities are not completely enclosed in a building are encompassed with protective fencing for exclusion of the public. Chain link fencing, six feet in height topped with three strands of barbed wire, is used around such stations.

The sites are usually located at the intersection of transmission line rights of way and within areas determined by environmental, ecological and social considerations. The orientation of the switching equipment on the site is selected to suit the transmission line egress and to achieve the least number of line crossovers. At large stations, the layout must usually accommodate a railway spur to the transformer positions on the main axis of the station. Gravelled service roads are provided in switchyard areas for maintenance vehicles. Care is taken to ensure that all turn radii on the service roads are sufficient to accommodate long vehicles such as mobile cranes.

Control and relay buildings, microwave towers and communication buildings, air compressor and oil handling buildings and maintenance buildings are located to minimize the cost of the service provided. Due to the large amounts of contained oil, transformer location and spacing are arranged to ensure that in the rare event of a fire in one unit, other equipment will not be affected.

FIGURE
3.2.4 - 3

1   Retaining oil pits with sumps are constructed around
2   all power transformers as an environmental
3   protective device to contain spillage and provide a
4   means of recovery in the event of the rupture of the
5   tank or radiators. As a fire prevention measure,
6   the pits are filled with gravel to restrict oxygen
7   to spilled oil which may have been ignited.

9   Wherever possible, a station water supply is
10   obtained from a local water main. A well is drilled
11   to provide water for most rural stations. In cases
12   where well drilling proves unsuccessful, a storage
13   tank is provided and arrangements made to truck
14   water to the station. A septic tank and bed
15   approved by local health authorities are required
16   when connections cannot be made to a local sewage
17   system.

19   Applicable portions of Ontario Hydro Safety Rules
20   (5) as well as portions of the Canadian Electrical
21   Code and other Regulatory Agencies govern the site
22   layout.

3.2.5   CONSTRUCTION PRACTICES

25   The engineering and construction of stations covers
26   all activity in the engineering office and on the
27   site, starting from the establishment of the power
28   diagram and the acquisition of the site, to the
29   placing in service of the completed station. This
30   period may be three and a half years for a major
31   station and/or two and a half years for a small area
32   supply (DESN) station. Usually the construction is
33   started well before design is completed in order to
34   compress the schedule.

36   Most sites must be rough graded to provide level
37   areas for the installation of station structures,
38   buildings, etc., and to provide adequate drainage of
39   these areas. Where large areas are involved and
40   significant differences in natural elevations must
41   be accommodated, terracing is permitted at
42   controlled locations depending on the type of
43   station.

45   As a first step, top soil is scraped and stockpiled
46   for later use on portions of the site to be seeded
47   or sodded. To the extent possible care is taken to

1 minimize erosion with soil runoff to local drainage
2 during the rough grading. The designer attempts to
3 balance the cut and fill when setting the rough
4 grades in order to minimize soil disposed or
5 acquisition requirements. Usually, immediately,
6 after the rough grading is completed, the station
7 chain link fences are erected to exclude the public
8 from hazardous areas. Landscaping can be initiated
9 on the areas external to the fence at this time.
10 Excavation for foundations, buried pipes, and cable
11 ducts, grounding, the construction of concrete forms
12 and the pouring of concrete proceed as in any
13 industrial installation. Most station buildings are
14 erected by contractors obtained through competitive
15 tenders. After the foundations are completed, the
16 finished grading is carried out. This includes the
17 addition of crushed stone in specific areas for
18 protection against touch and step potential hazards
19 and the sodding or seeding of the remainder of the
20 site. Erection of the steel supporting structures
21 and installation of the electrical power equipment
22 and the control metering and relaying then proceeds
23 and commissioning is initiated.

3.2.6   STATION EQUIPMENT

The increase in voltage levels from 115 kV in 1910
to 500 kV in 1966 and the large increase in power
handling capacity have depended on the development
of the technology required to build the station
equipment.

3.2.6.1   Power Transformers

The success of alternating current electric power
systems as entities for the supply of energy is due
to the development of the power transformer into a
reliable, highly efficient device.

Transformer ratings presently in service vary from
some old 8 MVA, 115 kV units at a small DESN station
to 750 MVA autotransformers used for the 500 to 230
kV bulk power system.

The 115 kV units being purchased today are 45/75 MVA
units and the 230 kV transformers being purchased
are rated 75/125 MVA.

All recently purchased transformers are three phase
units. That is, the windings of all three phases
are contained in one tank. For a conventional
double wound transformer, there is an iron core with
six windings on it, i.e. one primary winding and one
secondary for each phase.

The three phase transformer is the most economical
unit, both in purchase price and in cost of
installation. In a few installations where there
are stringent shipping limitations, single-phase
transformers (one core and 2 windings in each tank)
are installed as they are considerably lighter.

Weight is usually the most stringent shipping
limitation. A 500 kV 750 MVA autotransformer
typically weighs 350 tons stripped for shipping.
Ontario Hydro has purchased a special Schnabel car
for moving units of this weight on the railroad.
The 230 kV 75/125 MVA transformer typically weighs
110 tons stripped for shipping. All power
transformers have weights measured in tons and
moving them is never easy.

Energized transformers generate a sound at a
frequency of 120 Hertz. Before a transformer
station is constructed, night time ambient sound
levels are measured at nearby residences. Special
precautions are then taken at all new stations to
ensure that the sound level of the transformers will
not exceed the measured night time ambient level.
Ontario Hydro purchases transformers with maximum
permissible sound levels of 84 dB at 500 kV, 73 dB
at 230 kV, 70 dB at 115 kV, these being lower than
the equivalent NEMA standard levels of 91, 82 and 80
dB respectively. (6)

The transformers in most new installations are
installed within an acoustic enclosure. The
enclosure can be metal or heavy masonry for
particular installations. Through normal
attenuation, sound levels which penetrate the
acoustic enclosure are reduced to an acceptable
value at the boundary of the station site. (7)

The essential insulants in a transformer are the
paper wrapped about the winding conductors and the
oil in which the entire assembly is immersed. The

strength of the insulation is measured by its
ability to withstand a prescribed impressed
overvoltage wave referred to as its basic impulse
insulation level (BIL). 230 kV system transformers
purchased by Ontario Hydro have a 230 kV winding
strength of 900 kV BIL, i.e. the insulation of the
winding will withstand a voltage wave (similar in
shape to a lightning impulse) which rises to 900 kV
in 1-1/2 microseconds and decays to half peak (450
kV) in 40 microseconds. 115 kV transformers are
being purchased with a BIL of 550 kV and 500 kV
units are purchased with a BIL of 1425 kV.

The insulating oil also serves as an efficient
cooling system. Losses in transformers, appearing
as heat, are removed by circulating the insulating
oil through air cooled radiators. The oil and air
may circulate naturally by convection. Most large
transformers have their rating increased by the use
of pumps to circulate the oil and fans to force the
air. Transformers usually have a dual rating, such
as 75/125 MVA, i.e. 75 MVA continuously with natural
oil and air circulation, and 125 MVA continuously
with oil pumps and air fans operating. Transformers
are usually also considered to have an overload
capacity with calculated loss of life due to
overheating of the insulation.

Another important internal feature of a transformer
is its reactance which causes a voltage drop across
the transformer and increases with load. Within
narrow limits, the manufacturer can adjust the
reactance to suit the purchaser's requirements. The
voltage drop or regulation should be minimized. The
reactance also restricts the transfer of fault
current through the transformer in the event of an
insulation failure. This limitation of fault
current protects equipment in the system supplied by
the transformer.

Increases in load on a system results in a lowering
of voltage at the customers service entrance because
of transmission impedance and transformer
regulation. This introduces a need to raise the
voltage at the source transformer in order to
stabilize the voltage. Most area supply (DESN)
stations have transformers that can raise the
voltage automatically as the load increases.

1 3.2.6.2   Circuit Breakers

3   These are the devices used for closing and opening
4   the power circuits. They differ from load
5   interruptors in that they are rated as having a
6   capability to interrupt fault currents. These fault
7   currents are foreseen to be as high as 80,000
8   amperes on parts of the Ontario Hydro system in the
9   1990's, compared with our present maximum level of
10   63,000 amperes.

12   Circuit Breakers are called upon to perform four
13   basic functions:

15   (a)   Be an ideal conductor when closed.
16   (b)   Be an ideal insulator when open.
17   (c)   When closed be able to interrupt approximately
18   16 to 20 times its rated current promptly at
19   any instant without causing dangerous
20   overvoltages.
21   (d)   When open to close promptly at any instant
22   without being impaired by the flow of fault
23   current.

25   Power circuit breakers supplied at this time are of
26   3 main types:

28   (a)   Oil Circuit Breakers are used from 15 kV up to
29   230 kV. In these breakers, the interrupting
30   area is completely immersed in oil which acts
31   to quench the arc produced by opening the
32   contacts. These breakers have the advantage of
33   not requiring an auxiliary external air system
34   to assist the interrupting operation but from
35   time to time the oil becomes contaminated with
36   carbon particles and must be filtered to
37   maintain its quality. There is a certain fire
38   hazard associated with oil breakers. This
39   presents minimum risk outdoors, but is not an
40   acceptable risk indoors.

42   (b)   Air Blast Circuit breakers (15-500 kV) use
43   compressed air as an insulant and extinguish
44   the arc by a blast of air. Compressed air has
45   an insulation quality equivalent to oil but
46   without the attendant fire hazard. However,
47   air blast breakers do require a highly reliable
48   air storage and supply system to provide

3.2-10

extremely dry air in sufficient quantities for
several operations of all station breakers.
The requirement for separate current
transformers is an economic penalty where air
blast circuit breakers are used. Current
transformers are an integral component of the
bushings of an oil circuit breaker.

(c) Sulphur Hexafluoride Gas circuit breakers
employ SF6 gas with its excellent insulation
qualities. The SF6 breaker used with
conventional buses preceded SF6 switchgear by
some years. There are two families of SF6
breakers, one a single pressure unit, and the
other, which extinguishes the arc by means of
high pressure SF6 provided by a special
compressor. This high pressure (18 atmospheres
- 1820 kPa) requires heating since otherwise
the gas liquefies at 14 Degrees C at this
pressure.

(d) Vacuum Breakers are now being offered for use
at 115 kV and higher voltages but are still
considered developmental. None have been
purchased to date by Ontario Hydro.

Noise occurs on opening an airblast circuit breaker
as the high pressure air is exhausted to the
atmosphere after passing through the current
interrupting chambers. This noise, which is like a
sharp report and lasts momentarily, can be reduced
by the fitting of mufflers on some breakers.
Breakers may be operated many times while being
checked into service and then are seldom operated
thereafter. However, some units used to switch
capacitors or reactors may be operated on a more
regular basis. Gas and oil insulated breakers have
different and less sharp noise characteristics in
their operation and are not as noticeable as
airblast units.

3.2.6.3   SF6 Gas Insulated Switchgear

One of the most significant advances in station
equipment in the last decade is the development of
sulphur hexafluoride gas insulated switchgear.

3.2-11

More than one hundred gas insulated stations in the
70 kV to 420 kV range are in commercial service in
Europe. Some installations have been in service
since 1967. Similar type switchgear at 115 kV to
765 kV has been installed or is on order in North
America. There are also installations in Singapore
and Japan.

SF6 switchgear promises increased reliability,
reduced maintenance, reduced station costs, and
increased acceptability due to the substantial
reduction in station site areas.

With open switching the insulation of a 230 kV bus
is essentially a 12 foot Cylinder of free air. With
SF6 gas the bus can be accomodated in a 24" diameter
tube. As a consequence the use of SF6 insulated
switchgear has a major effect on the size of
switchyard areas and the entire station site. A gas
insulated 230 kV station occupies an area
approximately 16 to 20% of that required for a
station with conventional low profile outdoor
switchyards. In the case of 500 kV, it is about 10
to 14%.

Based on the compact nature of this switchgear and
the climatic conditions found in Ontario, it appears
prudent at present to install this switchgear in
buildings. The building will provide a superior
environment for erection, operation and maintenance
independent of weather. The stations are being
designed to terminate most of the 500 kV
transmission circuits directly on the switchgear
building. This will improve the overall appearance
of the station installation by eliminating the heavy
anchor line structures that would otherwise be
required.

Costs of particular elements of gas insulated
switchgear approach twice the cost of the similar
particular elements of air insulated switchgear at
voltages below 230 kV. However, the extremely
compact size of the SF6 switchyard results in
important cost reductions in the facilities (site,
roads, buildings, structures, control cables)
associated with the switchgear especially at
voltages above 230 kV. Since the major portions of

this gear are assembled in the manufacturer's plant, field labour costs should also be reduced.

3.2.6.4   Open Switching Buses

The main buses (8, 9) are the common connection points for all circuits entering the station. To ensure continuity of service, all transformer stations are built with two main buses. The most flexible, economical and compact station arrangement is achieved by arranging the two buses side by side at one side of the switchyard and connecting the diameters in which the circuit breakers and line terminations are located in a folded or U arrangement between them. (4)

There are two types of buswork used in stations -- strain and rigid. Strain buses are stranded cable conductors, either copper or aluminum suspended between steel structures and supported and insulated from the structure by porcelain strain insulator assemblies. (Fig. 3.2.4-2) Rigid buses are copper or aluminum tubes supported on rigid porcelain insulators mounted on steel structures. (Fig. 3.2.4-1)

The bus and its supports are designed to withstand without failure, the maximum short circuit forces as well as winds in excess of 80 mph or the additional weight due to 1/2" of ice. (8) Phase to phase and phase to ground clearances are selected to ensure a basic insulation level that is coordinated with the electrical equipment in the station. The centre to centre spacing of the buses is often larger than the minimum phase to phase electrical clearance spacing in order to reduce the magnetic forces on the bus due to fault currents. The probable fault currents which may occur at the station in the ultimate is forecast. A number of station designs based on different centre to centre bus spacings, bus diameters and supporting insulators are available as standards and the appropriate design is selected to suit. The standard bus designs are also rated according to their continuous current carrying capacity.

In the large 500 kV stations, the main bus consists of 12 inch diameter aluminum tubing and has a

continuous current rating of 8000 amperes. The
diameter bus is an 8 inch aluminum tube with a
rating of 4000 amperes.

Most existing stations were built with three levels
of bus. Most new stations are expected to have only
two levels. In both designs, the lowest level is
rigid bus. The standard height above grade of the
low bus is set to permit an operator on snowshoes to
walk safely under the bus. In Southern Ontario, the
minimum are 15 feet at 115 kV, 17 feet at 230 kV and
23 feet at 500 kV.

Upper bus levels must be supported above the lower
bus at a sufficient height to ensure phase to phase
clearance and also to provide working clearance
during maintenance on the lower bus. This results
in a minimum bus height of 29 feet at 230 kV and 50
feet at 500 kV. This sets the bus height of the Low
Profile Stations.

Buses and all energized equipment are designed to be
corona free. (9) Bus fittings are type tested at
Ontario Hydro's Research Centre. By specifying
adequate conductor size, spacing and by bundling of
strain buses, surface voltage gradients are kept
below the corona level. Voltage grading rings are
applied where equipment or hardware cannot be
streamlined.

3.2.6.5   Voltage and Power Factor Control Equipment

Only alternating current in phase with its
associated voltage produces useful energy. The
presence of inductive or capacitive elements in the
transmission system or the customer's load produces
additional current not in phase with the voltage.
To reduce these useless currents, the utility
introduces capacitance or inductance as required to
reduce the system losses which are a function of
total current.

Transformer stations are appropriate locations to
install capacitors, shunt reactors and synchronous
condensers for the supply of capacitive or inductive
vars as required for voltage regulation of the
system. It is usually most economic to connect this
equipment to the tertiary windings of the auto-

transformers at the bulk power stations. In those
cases where the size of the VAR equipment exceeds
the capacity of the tertiary winding, the equipment
is connected to one of the high or low voltage
buses. At DESN stations, capacitors are usually
connected to the low voltage bus.

(a) Capacitors

Capacitors are essentially two parallel sheet
foil surfaces separated by a sheet of
insulation, all immersed in a liquid insulant
and sealed in a metal tank with porcelain
bushings.

The capacity of the capacitor banks is usually
proportional to the voltage. Typical ratings
of banks on the Ontario Hydro system are 20
MVAR at 13.8 kV, 30 MVAR at 27.6 kV and 44 kV,
100 MVAR at 115 kV and 200 MVAR at 230 kV.

Capacitor banks at stations usually comprise
compact stacked assemblies of individual and
self-contained capacitor units to make up the
required bank size.

(b) Shunt Reactors

They are, in construction and appearance,
similar to autotransformers. They are usually
the autotransformer tertiaries at 500 kV and
some 230 kV stations and are used to suppress
voltages on the high voltage bus when the
system is unloaded or lightly loaded. The
usual rating is 50 to 150 MVAR at 27.6 kV.
Some 500 kV lines have been equipped with 41.7
MVAR shunt reactors. They are in construction
and appearance similar to power transformers.
The number of installations required is limited
in comparison to capacitors.

(c) Synchronous Condensers

Synchronous condensers are large rotating
machines with rotor and stator windings similar
to ac generators. By varying the current in
the field coils, the machine can be made to
operate as a generator of vars (similar to a

1 capacitor) or an absorber of vars (reactor).
2 Despite this versatility, static capacitors and
3 reactors are being installed at new stations in
4 preference because of the high initial cost and
5 high maintenance cost of the synchronous
6 condenser and its relatively high operating
7 losses.

9 3.2.6.6   Other Equipment

11 Though transformers, circuit breakers, buses,
12 synchronous condensers, static capacitor banks and
13 shunt reactors are the major power equipment in a
14 transformer station, there are several other power
15 devices that are installed in all stations.

17 (a)   Switches

19   Switches consist essentially of two types,
20   isolating and load break. Isolating switches
21   are used to disconnect from the system a piece
22   of equipment or a line which has failed, or for
23   which isolation is required for maintenance
24   purposes. Normally such switches are not
25   designed to be opened when current is flowing
26   in the switch. However, small currents, up to
27   15 amperes, may be interrupted by switches with
28   auxiliary arcing contacts, called horn gap
29   switches. Load break switches are used to open
30   a circuit when current is flowing and are
31   designed for this purpose. The capability of
32   such switches is limited and they are not
33   suitable for the interruption of large fault
34   currents. Switches may be manual or motor
35   operated.

37 (b)   Lightning Arresters and Spark Gaps

39   Lightning arresters and spark gaps (10) are
40   used to protect equipment such as transformers
41   from damage due to excessive over-voltage
42   caused by lightning or switching surges. When
43   an over-voltage occurs, the lightning arrester
44   or spark gap provides a low impedance path to
45   ground and discharge current flows to ground
46   thus reducing the over-voltage to a value below
47   the withstand level of the equipment
48   insulation.

51   3.2-16

(c) Current Transformers

Current transformers provide a means of
measuring the current flow in a circuit. The
primary of the current transformer is connected
into the circuit and the secondary of the
current transformer provides a low voltage and
low current signal, the low current being
proportional to the current flowing in the high
voltage circuit. This low current signal is
used to energize meters and protective relays.

(d) Potential and Capacitor Voltage Transformers

Potential transformers (PT's) and capacitor
voltage transformers (CVT's) provide a means of
measuring the voltage on a high voltage
circuit. The primary winding of the PT or CVT
is connected to the high voltage circuit. The
secondary winding provides a low voltage in the
primary winding thus providing a voltage signal
which can be used to energize meters and
protective relays. CVT's are also used for
line coupling with power line carrier
communications facilities (see 3.2.9.2).

(e) Grounding and Direct Stroke Lightning
Protection

Stations are protected from a possible direct
stroke of lightning by the installation of one
or more skywires or spires mounted at a
considerable height above the equipment and
buses and connected to ground.(11)

Buried ground buses consisting of copper cable
and ground rods are provided at all stations to
provide very low resistance to the flow of
fault currents. This is important in order to
reduce step and touch potentials within the
station and to reduce the voltage rise of the
station ground during power system
disturbances. On sites on rock or with high
resistivity soil, special grounding treatment
will be provided to reduce the grounding
resistance to acceptable levels. (12)

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(f) Station Service

Station service is the ac and dc supplies
needed within a station to supply the various
electrical needs of the station, such as
lighting, heating and control systems. A large
bulk power station would typically require a
1000 kVA capability of electric power to supply
the station service. A typical DESN station
requires 200 kVA.

(i) AC Station Service

The source for this power is usually the
high voltage system, but on occasion,
rural lines are brought into the
transformer station. Transformation is
provided to reduce the voltage to the 600
and 120 volts needed by motors, heaters
etc. Reliability is provided by having
duplicate supplies and automatic transfer
schemes. Diesel Generator Standby is
sometimes provided as a back-up supply
particularly at stations where the normal
service is from rural lines.

(ii) DC Station Service

This is provided from one or two
batteries. Again as in ac, there are
automatic transfer schemes, monitoring
schemes with alarms, etc.

3.2.7   CONTROL SYSTEMS

The power system is operated as an integrated multi-
tiered organization comprised of generating and
transformer stations, Regional Operating Centres,
and the System Control Centre located at Richview TS
in Toronto.

The System Control Centre directs the operation of
the transmission, switching and transformation of
the bulk power system (115 kV and higher) and it
directs the economic scheduling and loading of
generating facilities and the implementation of
transactions with other systems. To accomplish
this, the staff of the System Control Centre are
provided with telemetered quantities and equipment
status from across the system. This information is
now being supplied by a sophisticated Data
Acquisition and Computing System (DACS), which is
being commissioned at the present time. (13)(14)

Most transformer stations and hydraulic generating
stations are controlled from District Control
Centres by Supervisory Control Systems. As of Dec.
31, 1975, full-time operating attendance is
maintained at 40 transformer and switching stations
and 28 generating stations. Operators at the
attended stations are also responsible for control
of 169 non-attended transformer stations and 50 non-
attended hydraulic generating stations and the
switchyards at three large thermal generating
stations. They also direct sectionalizing by line
crews of all 115 kV and 230 kV transmission circuits
and many distribution circuits in rural areas.
Approximately 80% of the non-attended stations and
the three thermal generating station switchyards are
controlled by Supervisory Control Systems operated
over telephone circuits or microwave in some
instances, and the remaining 20% of the non-attended
stations have a simple alarm system to the District
Control Centre. Extensive use is made of radio
communication in directing line sectionalizing for
fault isolation or maintenance.

The earlier supervisory control equipment operated
on the basis of vibrating reed relays which were
tuned to respond to a limited range of tones
received from the remote equipment. This has now

1   been superseded by solid state equipment for most
2   applications. Ontario Hydro has purchased its first
3   Computer Assisted Supervisory Control and Data
4   Acquisition (SCADA) System, with delivery expected
5   in September 1976. This equipment is expected to
6   permit the control of many more stations from one
7   Control Centre. (15)

9   Every station is provided with a control building
10   from which all electrically operated equipment on
11   the station can be controlled. All important
12   electrical quantities and equipment status required
13   for operating the station are displayed in the
14   control room. In the event of trouble with the
15   supervisory control equipment, the station is
16   operated from the local control room by an operator
17   dispatched to the location for this purpose. An
18   operator must also be dispatched to an unattended
19   station in the event of apparatus failure, equipment
20   malfunction or planned maintenance which requires
21   on-site switching. The frequency of the requirement
22   for on-site attendance and the probable time
23   required for an operator to reach each of the
24   unattended stations, together with the effective
25   range of radio communications, are the principle
26   factors involved in the location of District
27   Operating Centres.

28 3.2.8   PROTECTIVE RELAYING SYSTEMS

30 3.2.8.1   Introduction

32   Every component of a power system, from the
33   generator to the customer, which operates at a
34   voltage level above ground is subject to the
35   breakdown of the isolation or insulation to ground
36   or to other conductors. The most notable example of
37   this is the effect of lightning on transmission
38   lines. When this occurs the resulting shunt fault
39   or short circuit condition can impose a sudden and
40   sometimes violent change on system operation.
41   Enormous currents can flow accompanied by the
42   localized release of vast quantities of energy. If
43   this is not immediately corrected serious damage to
44   equipment can result and/or the various generating
45   sources can pull out of step with each other and the
46   system collapses. Similarly, the failure of power
47   system control equipment, such as switchgear, to

operate as intended can also lead to damage and
service interruptions. It is the primary function
of protective relaying to recognize when such faults
or malfunctions are occurring, assess their severity
and location and initiate disconnection of the
faulty component or take some other corrective
action, automatically, in the shortest time which
can be practically and consistently achieved and is
economically warranted.

3.2.8.2   General Description of a Typical Protective
          Relay Scheme

In Ontario Hydro a typical protective relay scheme,
such as would be applied on a high voltage
transmission line, is composed of a number of
discrete individual elements purchased from a
variety of manufacturers. These elements are
assembled into a complete working system whose
operation is designed to meet the standards,
policies and practices developed within the
Corporation. Where a disturbance can effect
interconnected utilities, the criteria set forth in
the Northeast Power Co-ordinating Council Bulk Power
System Protection Philosophy are applied. (16)

Major elements of a complete relay scheme are:

(a)   Current and voltage transformers, necessary to
      provide a measurement of the currents and
      voltage pertaining at high voltage levels to a
      remote location at low or safe voltage levels.
      (3.2.6.6)

(b)   Fault detecting relays which can be considered
      as dedicated analog computers receiving the
      measured signals and by their level and inter-
      relationship determine and initiate the
      corrective action required. These devices can
      be relatively simple or extremely complex and
      are the heart of the protective scheme.

(c)   Auxiliary relays which accept the signal from
      the fault detecting relays providing the trip
      logic while performing the function of the
      interface between the fault detectors and the
      switchgear.

(d) Communication channels to transmit or receive switching instructions to or from a remote location, such as the other end of a transmission line, or provide additional information on which the appropriate local trip logic is dependent.

(e) Various other periphery or ancilliary devices to

(i) Facilitate maintenance and testing procedures

(ii) provide an uninterrupted power supply to the relay scheme

(iii) protect sensitive devices against the effects of voltage surges

(iv) provide an indication to the power system operators of what has occurred automatically and why

(v) high speed recording of electrical quantities to allow analysis of equipment performance under fault conditions

(vi) restore the faulted power system component to service automatically if the fault is transient.

3.2.8.3   System Relaying

Besides protective relaying schemes which are dedicated to the detection of faults within a well defined zone there is a type of relaying employed which oversees the general health of the power system as a whole and initiates automatic high speed remedial action as required. For example, should the system load suddenly exceed the generation available the resulting decline in system frequency will be recognized and sufficient load will be disconnected to restore a balance or, should the opening of a high voltage circuit leave inadequate transmission facilities remaining to carry the available generation to a load centre, that level of generation will be immediately reduced. Such system relaying, in general, is intended to limit the

1   number, extent or duration of widespread outages to
2   our customers and disturbances to the interconnected
3   utilities.
4

5   3.2.8.4   Standardization
6

7   As much as is practical to do so the designs for
8   protective relay schemes have been standardized to
9   accommodate the various types of power system
10   components such as generators and transformers,
11   which are added as the system grows and which
12   present the same or similar application problem.
13   This has the advantage of reducing design manhours
14   to that required to adapt a standard to meet a
15   particular situation. It permits the bulk purchase
16   of relay equipment, allows the manufacturers to
17   appreciate how we intend to use his products and
18   reduces the number of check-in-service and routine
19   maintenance procedures required of the field staff.
20   Over 90 such standards have now been developed and
21   are being applied.
22

23   3.2.8.5   Future Developments
24

25   As the system load continues to grow Ontario is
26   passing through a period where the existing
27   transmission facilities are called upon to operate
28   at power levels significantly higher than what could
29   be considered normal. As a consequence, protective
30   relay schemes of greater sophistication in design
31   and application are required to distinguish reliably
32   between a fault and those very high power levels
33   which, under certain conditions, can appear as a
34   fault to the relays. Several devices are now being
35   designed and developed within the Corporation to
36   meet this challenge. These devices have operating
37   characteristics and principles not presently
38   available from relay manufacturers.
39   Power system components such as generators and
40   transformers continue to increase in unit size thus
41   achieving higher operating efficiencies. Although
42   the probability of faults or failures occuring
43   within this equipment is not necessarily affected by
44   size, the financial consequences of any fault damage
45   which forces the equipment out of service is.
46   Therefore, the associated protection schemes,
47   particularly for generating units, are expected to
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51   3.2-23
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1		increase in extent and complexity in order to
2		minimize the probability of sustaining a damaging
3		fault.
4		
5		
6	3.2.9	MICROWAVE SYSTEM AND COMMUNICATION FACILITIES
7		
8	3.2.9.1	Introduction

The transmission of electrical energy from the generating stations to the transformer stations and load centres and the interconnection of the power system with other power systems has resulted in the development of extensive communications facilities for voice communication, telemetering, supervisory control, data acquisition, and protection signals transmitted between control centres and generating stations, transformer stations and switching stations.

A variety of transmission media is employed for communication in a transformer station depending on the required bandwidth, on economic and various technical factors. The power system is unique in that it can provide a very reliable physical path, viz. the power lines which interconnect the points of generation and supply, between which signals can be transmitted by means of a high-frequency carrier. In addition to power line carrier, microwave radio, and a limited Hydro-owned cable system, leased facilities from Bell Canada or other private telephone companies provide the required services. The choice of the communication medium depends upon economic, technical and geographical factors and is influenced primarily by the requirements of the protective relaying system and also by the number of channels required for voice communications for power dispatching, data transmission, supervisory control and other similar services, since all communiications systems do not have the same channel capacity.

3.2.9.2   General Description of Typical
           Communications Systems

(a)   Cable Systems

      Cable systems can be provided by Ontario Hydro
      or they may be leased from the telephone
      company. They are employed primarily for the
      transmission of relay protection switching
      instructions to a remote location or to provide
      information from a remote location on which the
      relay protection tripping logic at a local
      station is dependent. Cable circuits can also
      be used for control purposes and for
      administrative communications.

      Communications cables entering transformer
      stations are subject to a hostile environment,
      which is the major cause of circuit
      disturbances. The disturbances are caused by
      ground potential rise, voltage induction,
      lightning and switching surges or electrical
      contact between power and communications
      conductors. In order to reduce hazards to both
      equipment and personnel, protective equipment
      such as carbon blocks, heat coils, neutralizing
      transformers and isolation transformers, are
      installed as required.

      Cable systems provide satisfactory and
      economical service generally over short
      distances in urban or suburban areas where
      alternative routing is available.

(b)   Power Line Carrier

      The reliability of power line conductors for
      the transmission of information is very high
      and this medium has been used extensively for
      the most economic transmission of a small
      number of channels over relatively long
      distances. A power line carrier system
      consists of three distinct subsystems

      (i)   The high voltage line which must provide a
            satisfactory bearer medium for the
            transmission of high frequency signals
            between power stations.

(ii) The line coupling equipment which provides
a means of connecting the carrier
equipment to the line without undue loss
and to protect the power line carrier
(PLC) equipment. Essentially the coupling
equipment is comprised of:

- A coupling capacitor which is provided for
a dual function - as a capacitive voltage
transformer (CVT) as described in section
3.2.6.6 and to couple the high frequency
low potential signal to the low frequency
(60 Hz) high potential transmission line.
It is located in the switchyard at the
line entrance position.

- A line trap which is connected in series
in the power line at the point where the
coupling capacitor is connected to the
line and station bus. The trap serves to
provide isolation at certain high
frequencies between the power line and
station elements. The electrical
characteristics such as nominal current
rating, symmetrical mechanical and thermal
short circuit ratings must be such as to
meet the demands imposed on the trap
during static and dynamic states in the
power network.

- Coupling devices comprising transformers,
arrestors, inductors, capacitors, and
resistors between the coupling capacitor
and the carrier equipment to provide a
satisfactory path for the high frequency
signals and to provide protection and
safety for PLC equipment and personnel.

(iii) The PLC equipment is comprised of
transmitters and receivers that operate
primarily in the frequency range 30 -
200KHz at powers varying from one watt to
one hundred watts. Amplitude or frequency
modulation is employed and such equipment
is mounted on racks or in cabinets that
are usually located in relay buildings for
convenient connection to the transformer
station protective relaying or control

3.2-26

equipment. The power supply is obtained from the station battery or in some cases from a 48 volt D.C. power supply.

(c) Microwave Radio

As the power transmission facilities grew more complex, and from the experience gained from the November 1965 blackout, more sophisticated protective relaying schemes were developed to meet the increased demand for reliability and security of the power network. As a consequence, additional protection signalling channels were required for the direct tripping of circuit breakers at the remote end of the line, for transferring discrete information from the protective relays at one end of the line to those at the other for permissive or blocking functions and to transmit analog information between the protective relays at each end of the line for comparison purposes and tripping logic. The increase in demand for protection functions and for other channels for present and future needs led to the establishment of a microwave radio system which could provide a medium independent of the power transmission system that would be very reliable and that would have the channel capacity to carry protection, supervisory and control information.

The use of frequency modulated microwave radio is widely recognized as a flexible, reliable and economical means of providing inter-station communications. When used with appropriate multiplex equipment, it can carry a wide variety and number of circuits from simple voice channels to wide band channels for high speed data transmission. In accordance with federal government regulations, the microwave system operates in the 7125 - 7725MHz band which can provide up to 960 voice grade channels although to date 600 channel capacity has been the maximum used in the Ontario Hydro system.

In a typical transformer station, the major elements of the microwave system will comprise

a tower, antenna and waveguide system, radio
and multiplex equipment, tone signalling
equipment for protection and control, and
associated power supplies. In addition
telephone order-wire and supervisory equipment
is provided for maintenance and alarm
reporting. The following is a brief
description of each major element.

(d) Microwave Tower

The microwave tower is essentially a rigid self
supporting structure to support the microwave
antenna and may vary in height from 150 feet to
over 400 feet. The height is determined by the
distance and topography of the terrain between
stations because the microwave beam requires an
unobstructed line of sight path and behaves
much like a light beam insofar as atmospheric
influences are concerned. Unfortunately many
factors influence the choice of sites for a
transformer station and the microwave system
designer does not always have the best
conditions with which to choose the optimum
design and therefore must contend with less
than ideal conditions on transformer stations
in many cases.

The tower, being the highest structure in the
station, provides lightning protection for the
station and has reduced the requirement for
lightning protection structures on the new
stations. The tower is solidly grounded at
each leg and is connected to the station ground
grid in at least two places. The tower is
designed in accordance with a C.S.A. (17)
specification and can withstand wind loadings
up to 48/32 lbs./sq. ft. with exposed surfaces
of all tower members covered with 1/2"
thickness of radial ice. It is lighted and
painted, as required, by regulations of the
Federal Department of Transport, Air services
Branch. In an effort to improve the station
appearance, recent tower designs were changed
from a four legged, angle iron, straight sided
structure to a more aesthetically designed
tower with three tubular steel legs that are
flared to present a more pleasing appearance.

3.2-28

1	(e) Antenna and Waveguide System
2	
3	The microwave antenna is a device for
4	collecting and focusing divergent radiation
5	into a parallel beam in much the same way that
6	an optical lens focuses a light beam. The
7	microwave "lens" is an aluminum parabolic
8	reflector which is illuminated by a flared
9	waveguide that transmits and receives the
10	microwave energy to and from the microwave
11	transmitter and receiver. The antenna can vary
12	between 6ft. and 12ft. in diameter and is
13	located at a height on the tower and oriented
14	in the direction which meets the propagation
15	criteria to adjacent stations in the microwave
16	network. The mounting is extremely rigid and
17	the antenna and waveguide are capable of
18	withstanding wind velocities up to 100 miles
19	per hour and gusts up to 150 miles per hour.
20	The waveguide runs are attached to the tower
21	legs and by a waveguide bridge between the
22	tower and radio building. The more recent
23	installations employ flexible waveguide which
24	is much easier to handle and install, and
25	requires less installation hardware.
26	
27	(f) Radio and Multiplex Equipment
28	
29	The microwave radio and multiplex equipment is
30	usually housed in a control or relay building
31	if possible. Otherwise a building is provided
32	at the tower base for this purpose. In order
33	to keep waveguide losses to a minimum, the
34	tower should be located adjacent to the
35	building in which the equipment is housed and
36	should a tower installation conflict with other
37	station structures, the tower and a separate
38	building are constructed on the periphery of
39	the station.
40	
41	The radio building is heated and air
42	conditioned to meet the ambient temperature and
43	humidity conditions specified by the supplier
44	of the equipment. The A.C. power supply is
45	provided from the station service and duct
46	facilities are constructed for inter-building
47	cables. Space is provided for duplicate 48
48	volt batteries, associated chargers and power
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1 distribution units that supply power to the
2 radio, multiplex and auxiliary equipment. The
3 status of the microwave system is monitored by
4 a supervisory alarm system which annunciates
5 essential information at the microwave alarm
6 centre located at the Richview System Control
7 Centre.
8
9 (g) Tone Signalling Equipment
10
11 The tone signalling equipment, as applied to
12 protective relaying, is identified as
13 protection tone equipment. Such equipment is
14 always located in close proximity to the
15 protection relays in order to reduce the amount
16 of cabling and cable exposure to extraneous
17 voltages. This equipment is interconnected
18 with the associated relays for the transmission
19 or reception of tripping, permissive or analog
20 commands and is mounted on racks in relay
21 buildings. 48 volt power supplies are also
22 provided to power the tone equipment and in
23 special cases to provide power for selected
24 protection relays. Multi-conductor cables are
25 installed between relay buildings and the radio
26 building to interconnect the tone signalling
27 equipment with the multiplexed voice channels.
28 Suitable shielding and isolation transformers
29 permit reliable and safe operation during fault
30 conditions.
31
32 Tone signalling equipment and associated
33 transmitters/receivers for telemetering, and
34 data acquisition are installed in convenient
35 locations that require a minimum amount of
36 cabling and exposure.
37 3.2.9.3 Engineering and Supply
38
39 Cable and power line carrier systems are designed
40 and specified by Ontario Hydro staff. Tendering
41 specifications for equipment are written by the
42 design engineers and following award of the
43 business, detailed design and drawing production
44 proceed on the basis of the type of equipment
45 supplied. Field installation is performed by Design
46 and Construction Department field staff or by
47 regional forces.
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51 3.2-30
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1	On the other hand, the microwave system is provided
2	on an Engineer, Furnish and Install basis.
3	Corporation engineers prepare a basic design and
4	performance specification for a microwave system to
5	meet specific criteria. The supplier is responsible
6	for the system design, equipment design and
7	installation, which includes all drawings and
8	instructions. Civil works such as roads, site
9	preparation, towers, buildings and fencing are all
10	provided by the prime contractor.

3.2.10   <u>MAINTENANCE FACILITIES</u>

Apart from their basic functions of switching,
transforming and operating, a large transformer
station or a station located near a large population
centre may have maintenance and service facilities
located on site. Office facilities may be provided
for supervisors, maintenance technical staff,
protection and control technical staff and
administration. Repair shops may be provided for
equipment and for instruments and relays. Indoor
and outdoor storage facilities may also be included.

It may not be possible to site the station in all
cases for access by railroad. It then becomes
necessary to rely on road transport from a railhead.
Not only is this transport facility essential for
the construction phase, but in addition it must
remain available and unrestricted for the life of
the station to replace transformers and other major
equipment that may suffer a failure in service.
When such failures occur replacement must be made
without delay to restore reliability of supply to
the load. This will require pre-planning and prior
arrangements for such situations as the half-load
season on the roads.

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